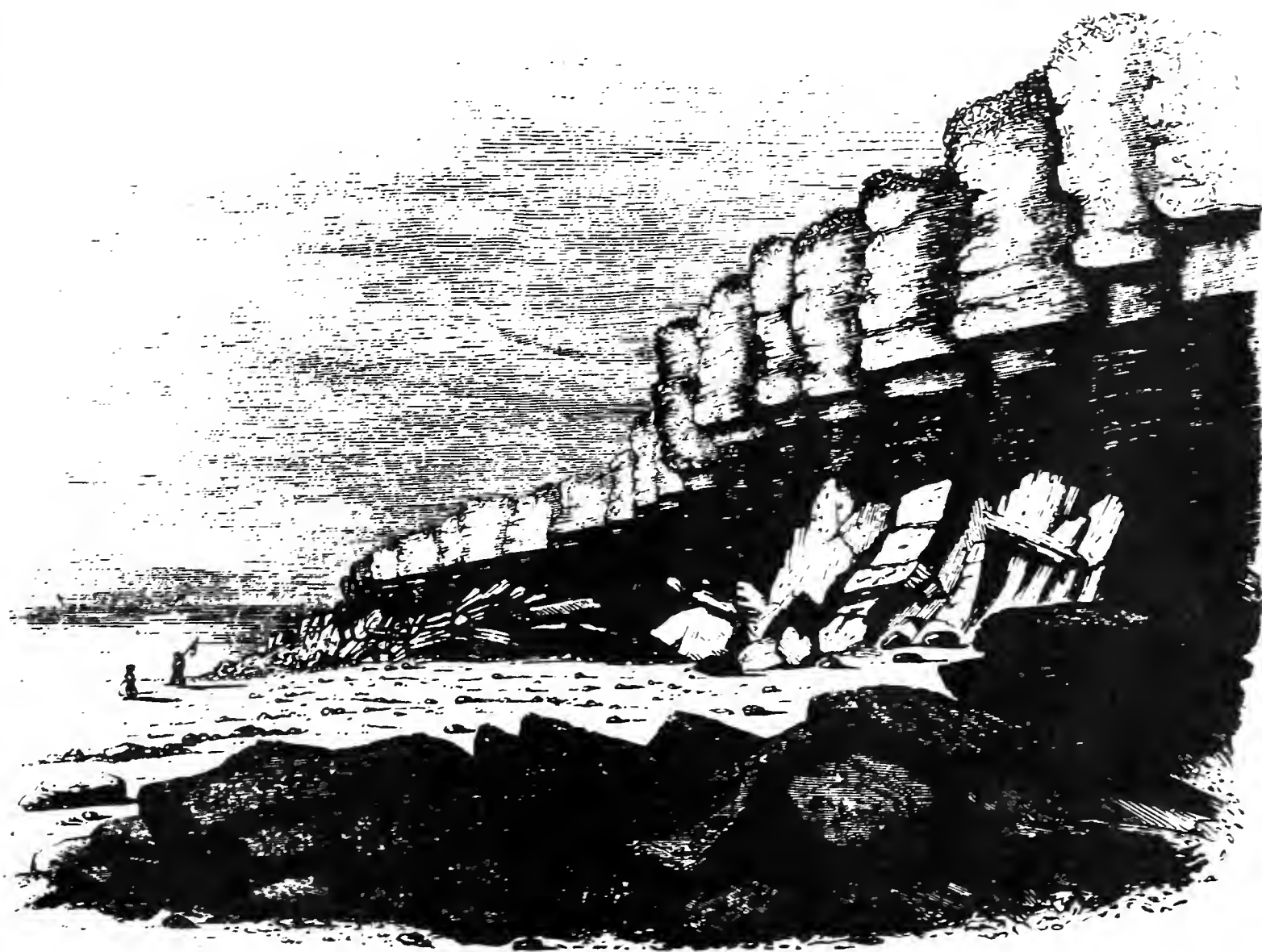6

BULLETIN OF THE GEOLOGICAL SOCIETY OF NORFOLK

No. 19

CONTENTS INCLUDE:

Soil surveying in Norfolk and Suffolk – "Iron mineral geodes" – Drift near Cromer – Breckland Field meeting.

CONTENTS

The Geological Society of Norfolk exists to promote the study and knowledge of geology, particularly in East Anglia, and holds monthly meetings throughout the year.

Visitors are welcome to attend the meetings and may apply for election to the Society. For further details write to the Secretary, Castle Museum, NORWICH, NOR 65B.

Copies of this Bulletin may be obtained 60p (post free) from the Society at the Castle Museum, Norwich, NOR 65B; it is issued free to members.

Also available at 75p (post free) is "The Geology of Norfolk", a 108 page book describing the geology of the county, reprinted by the Society in 1970; members of the Society may buy one copy only at 40p.

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EDITORIAL

This Bulletin continues in a new format the
Bulletin of the Geological Society of Norfolk
(formerly the Paramoudra Club).   Earlier numbers,
which were produced by duplicator from 1952 to 1970
are still available from the Hon. Secretary (for
address see back cover) at 18p per copy, (20p
inclusive of postage).

It is hoped that the more permanent form of this
publication will attract a greater variety of papers
than hitherto, on any topic relating to the geology
of East Anglia, and I shall be very glad to receive
manuscripts, preferably typewritten, at any time.
For the next issue, due out in the late summer or
early autumn of 1971, I should receive these as soon
as possible and no later than June 30, 1971.   My
address is: 116 Gowing Road, NORWICH, NOR 4OM.

R. S. J.

SOIL SURVEYING IN NORFOLK AND SUFFOLK

W.B. CORBETT

This paper describes the soils and soil patterns
found in three parts of East Anglia: the Brecklands in
the centre, the Beccles area in the east, and the
Cromer Ridge in the north-east.

The present policy of the Soil Survey of England
and Wales is detailed mapping of selected Ordnance
Survey 1:25,000 sheets.   The selected sheets for
Norfolk and Suffolk are shown in Fig.1.   In this
programme, started in 1967, the Beccles sheet TM49
and the Cromer Ridge sheets TG13 and 14 have been
completed, and the Horning sheet TG31 is being
surveyed.   Prior to this programme, from 1947 to
1966, the Survey used mainly third edition O.S.1"
base maps, and mapped areas of 216 square miles
selected for the agricultural importance of the soils.
80 square miles in Breckland were surveyed between
1960 and 1963 as a special project for the Forestry
Commission and Nature Conservancy.   The selected
1:25,000 sheets in the present programme, each covering
about 38 square miles, will serve as the basis for
1:250,000 maps of counties, the 1:25,000 sheets being
chosen as representing typical landscapes.   The 1/4
inch maps will be largely produced by extrapolating
major soil boundaries with the aid of relief maps or
stereoscopic aerial photographs.

Each area has a distinctive group of soils
arranged in characteristic patterns and these will be
used to illustrate the two aims of soil survey, namely
classification and mapping.

First, however, some soil definitions:
Soil - the surface zone above unweathered 'rock',
influenced by three general processes: the addition to
the surface of organic matter, physical and chemical

King's Lynn

N O R F O L K

NORWICH

Great
Yarmouth

Lowestoft

Thetford

Bury St. Edmunds

S U F F O L K

IPSWICH

Felixstowe

Harwich

| 0 | | 10 | | 20 | | 30 miles |
| 0 | 10 | 20 | 30 | 40 | 50 kms |

Selected
1/25000 sheets

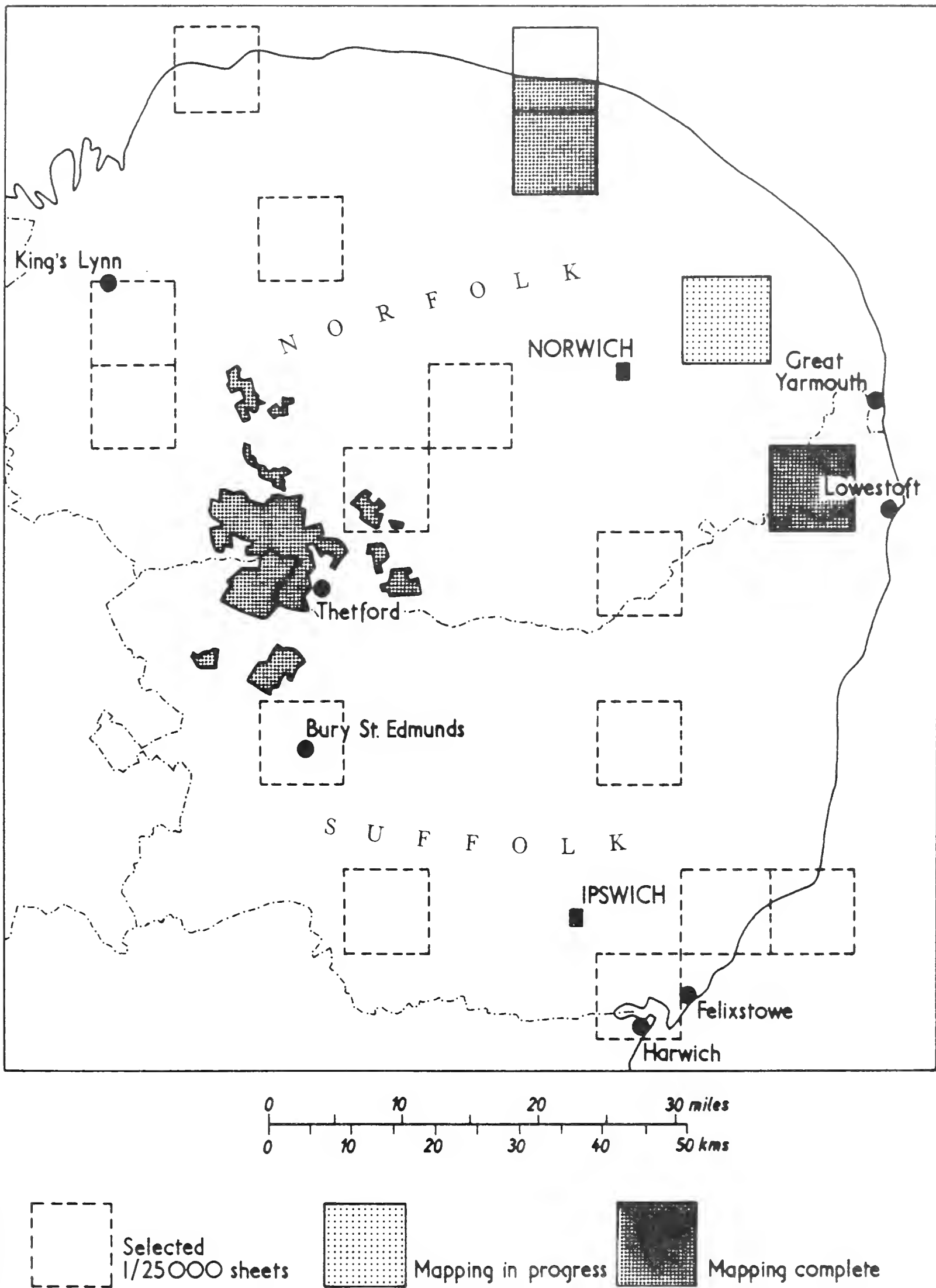Mapping in progress

Mapping complete

Fig. 1   Location and Policy

weathering, and the translocation of constituents.
These processes combine to differentiate the zone
into roughly horizontal layers known as horizons,
the sequence of these between the unweathered 'rock'
and the ground surface being known as the soil profile.
Processes of importance in classification are
decalcification, the removal in solution of $CaCO_3$;
lessivage, the translocation in suspension of clay;
podzolization, the translocation downwards of colloidal
humus, iron and aluminium, alone or together, following
chemical weathering of clay minerals in the upper
profile in acid conditions; and gleying, the reduction
and translocation of iron salts in anaerobic conditions.

Individual horizons in a soil profile are described
separately, and annotated according to their nature in
relation to soil formation.   Five main annotations are
used - A, B, C, E and g:-

A   the surface horizon whose colour is determined
    largely by its organic matter content.

B   the weathered subsoil, differentiated from the
    unweathered substrata by colour, largely of
    hydrated iron compounds, or by structure.

C   the little altered rock or parent material below.

E   horizons which have lost clay, or humus, or iron
    and aluminium; the suffixes t,h and fe being
    added to B horizons in which translocated material
    has accumulated.

g   a suffix indicating gleyed horizons.

Soil classification at the lowest level involves
the grouping of similar profiles into soil series, the
basic taxonomic unit.   Where covering large areas, this
is also a mapping unit.   Series are given the name of
the place in which they were first found or where they
are widespread.   A series has a particular arrangement
of horizons, indicating predominance of a specific soil-
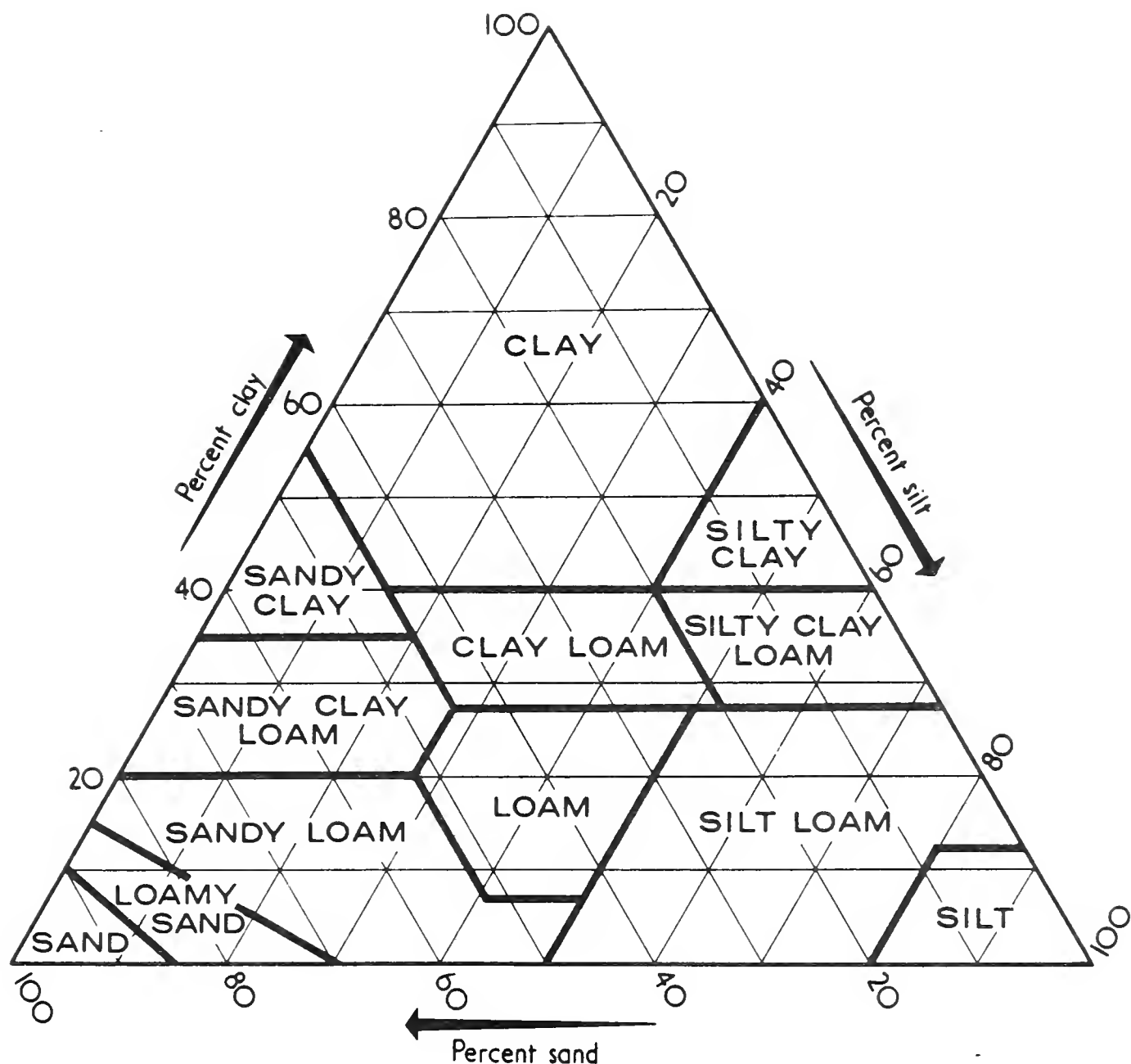forming process, a range or sequence of textures, a

Fig. 2   Soil texture

particular moisture regime, and falls in one or possibly
two <u>soil drainage classes</u>.

The main texture classes used by the Survey are
shown in Fig.2.   The three co-ordinates are: clay up to
2 microns, silt 2 to 50 microns, and sand 50 microns to
2 mm., each <u>textural</u> <u>class</u> being defined by a particular
range of percentage composition for each of the fractions.

Soil drainage classes, Fig.3, are defined by the
depth to, and frequency of, saturation, and in this
country particularly by the rise in regional or local
water tables in winter.   The depths of 30, 60, 90 cms
are chosen in relation to agricultural land use, months
being used as the time unit.   The five drainage categories
are, well-drained, moderately well-drained, imperfectly
drained, poorly drained, and very poorly drained.

For example, an imperfectly drained soil is saturated
within 30 cms of the surface for less than three months
in the year, and at depths between 30 and 60 cms for up
to 6 months.   Each moisture regime, so defined, is
associated, in general terms, with a particular profile
morphology.   In the diagram, long-term saturation
resulting in gleying is shown by coarse stippling, and
short-term saturation causing ochreous mottling by the
finer stipple.

Breckland Drift Soil Pattern

The Brecklands in central East Anglia lie in a
gap in the Chalk escarpment between Newmarket and
Swaffham.   The main upland surface, at just over 100
feet, drains to the west by three rivers to the Great
Ouse.   The landscape (Fig. 4), except for the upland
facet, consists of extensive gentle slopes of about 2
degrees, with relatively narrow terraces at between 25
and 50 ft.   Dry secondary valleys intersect the uplands,
and where these drain directly to the Fens the lower
valley floors are extensive and delta-shaped.

Over 90 per cent of the soils of this landscape are
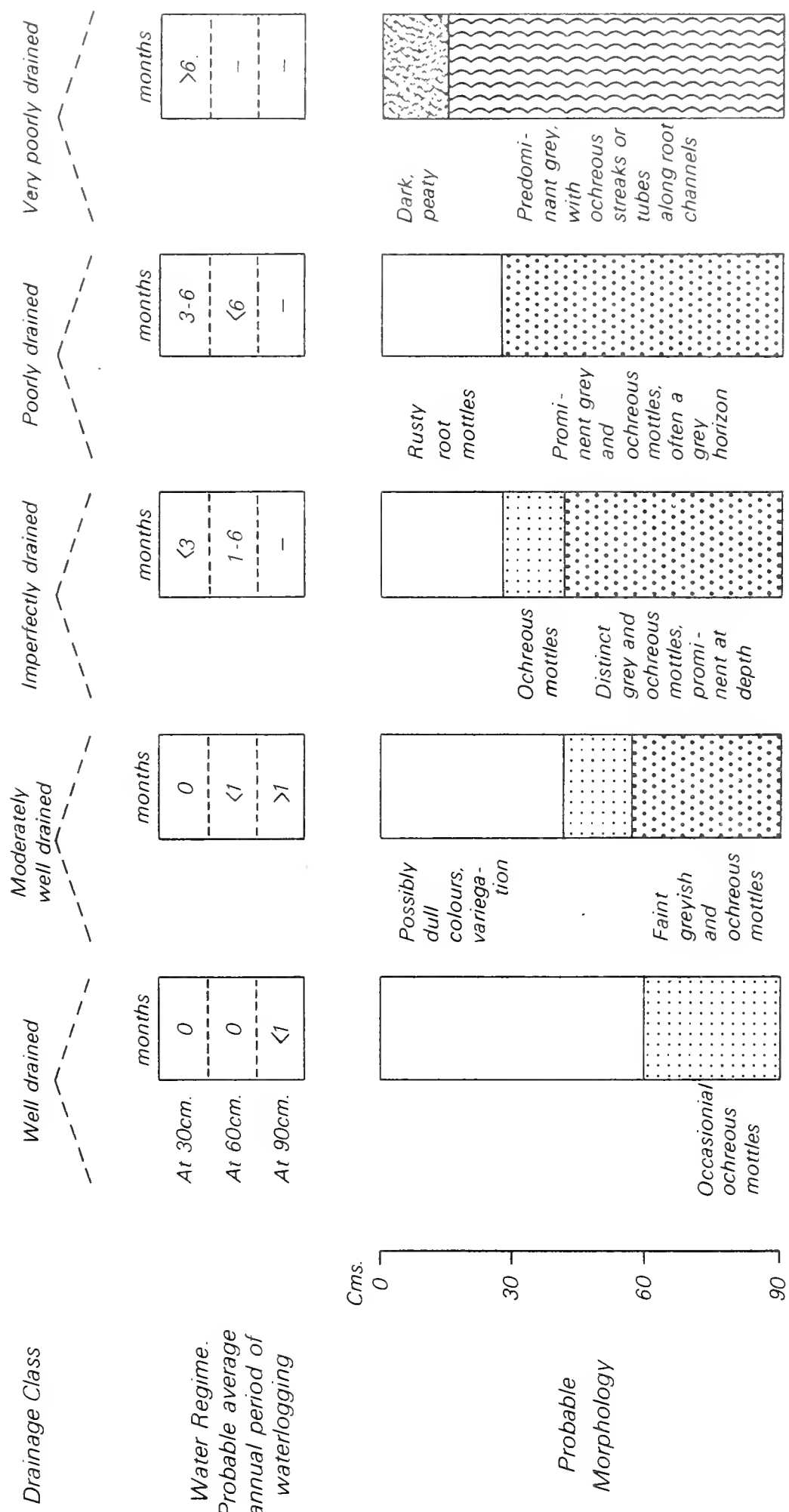on one parent material, a drift almost entirely of chalk
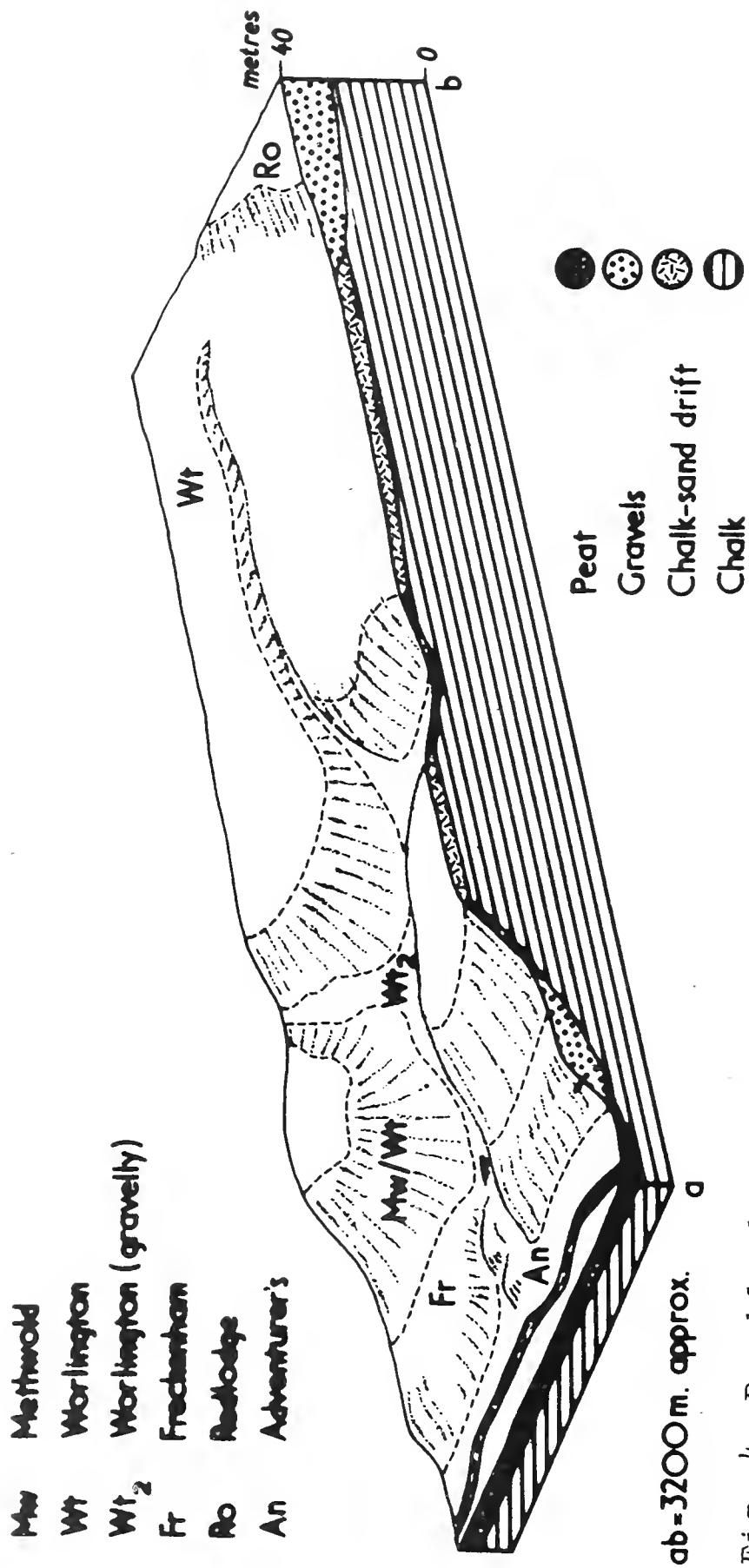
Fig. 3   Soil drainage

The figure shows a chart of soil drainage classes with the following structure:

Drainage Class	Well drained	Moderately well drained	Imperfectly drained	Poorly drained	Very poorly drained
Water Regime. Probable average annual period of waterlogging	months	months	months	months	months
At 30cm.	0	0	<3	3-6	>6
At 60cm.	0	<1	1-6	<6	–
At 90cm.	<1	>1	–	–	–

Probable Morphology (depth in Cms.: 0, 30, 60, 90):

- Well drained: Occasional ochreous mottles
- Moderately well drained: Possibly dull colours, variegation; Faint greyish and ochreous mottles
- Imperfectly drained: Ochreous mottles; Distinct grey and ochreous mottles, prominent at depth
- Poorly drained: Rusty root mottles; Prominent grey and ochreous mottles, often a grey horizon
- Very poorly drained: Dark, peaty; Predominant grey, with ochreous streaks or tubes along root channels

Grey colours of Munsell chroma <3 in values 4 or more, or, Munsell chroma 3 in values 6 or more

Munsell chroma 1 or less, or hues bluer than, or greener than 10Y dominant

Fig. 4 Breckland - landscape and soils

Mw   Methwold
Wt   Worlington
Wt₂ Worlington (gravelly)
Fr   Freckenham
Ro   Redlodge
An   Adventurer's

Peat
Gravels
Chalk-sand drift
Chalk

ab=3200m. approx.

and sand forming a very shallow skin over the Upper Chalk.
The remaining ten per cent are on Sand and Gravel, on
terraces and occasional upland caps or knolls, and on the
floors of dry valleys.

The morphology of the drift soils is shown in Figs.
5 and 6.   These are all well drained, with textures of
sand or loamy sand.

Newmarket Series - a shallow calcareous soil with two
horizons, the surface A horizon with humus incorporation
covering the little altered C horizon of chalk-sand drift.
The main soil-forming process is decalcification.

Methwold Series - relatively shallow calcareous soils
with three horizons, the A and C as above, with a brown,
slightly calcareous B horizon partly decalcified, and
without humus between.   The main soil-forming process
is also decalcification.

Worlington Series - a deep acid soil with four horizons,
an acid A horizon with humus over a broad Eb horizon from
which some clay has been eluviated.   Below, at the chalk-
sand drift surface, is a distinctive thin reddish brown
layer of sandy loam or sandy clay loam.   This is a Bt
horizon formed, at least in part, by translocated clay.
The C horizon is the unaltered chalky drift.   The main
soil process is lessivage, the eluviation of clay follow-
ing decalcification from the acid upper profile and its
accumulation at the calcareous drift surface.

Santon Series - a deep, markedly acid, soil with six
horizons, having an A, Ea, Eb, B, Bt, C, horizon sequence.
The A with much organic matter, and bleached grains is
over a slightly indurated Bh horizon, dark or black and
with sand grains cemented by translocated colloidal
humus.   Below is a Eb, Bt, C horizon sequence similar to
the Worlington series.   The dominant soil-forming process
is podzolization, here mainly the translocation of
colloidal humus from the surface to the upper part of the
profile.

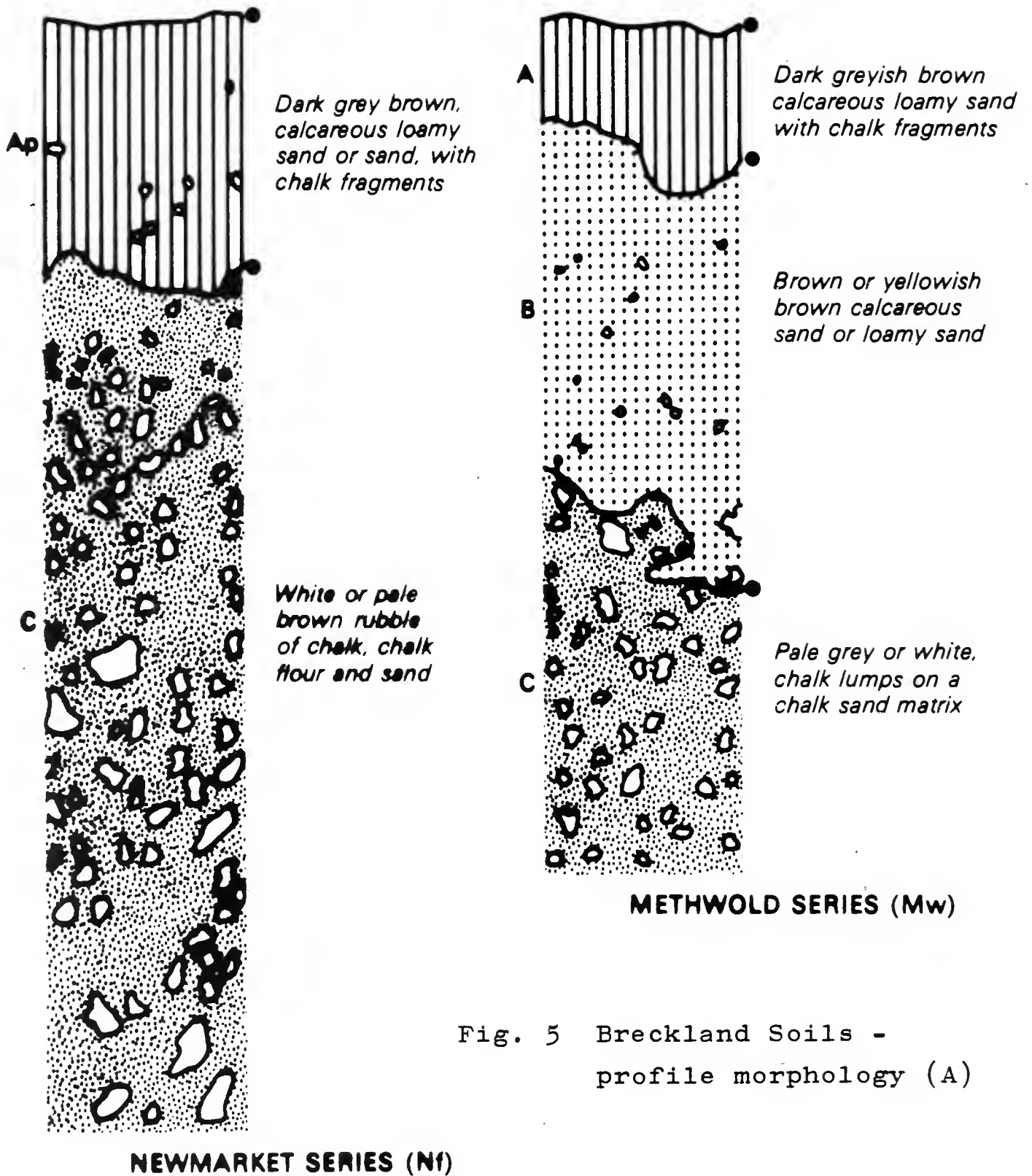The four soils form a pedological sequence, although

Dark grey brown, calcareous loamy sand or sand, with chalk fragments

White or pale brown rubble of chalk, chalk flour and sand

Dark greyish brown calcareous loamy sand with chalk fragments

Brown or yellowish brown calcareous sand or loamy sand

Pale grey or white, chalk lumps on a chalk sand matrix

METHWOLD SERIES (Mw)

Fig. 5   Breckland Soils - profile morphology (A)

NEWMARKET SERIES (Nf)

Ap 1 — Black amorphous humose sand

Ap 2 — Dark grey brown, grey brown or brown, sand or loamy sand, slightly stony

Eb — Brown, pale brown, or pale yellowish brown, sand, slightly stony

Bt — Strong brown, sandy loam

C — Pale yellow brown to very pale yellow brown chalk sand mixture with chalk lumps

WORLINGTON SERIES (Wt)

A — Black humose sand

Ea — Greyish brown (dry), black (moist), loose sand with bleached grains

Bh — Dark brown, slightly cemented sand

Eb — Brown to yellow brown sand

Bt — Reddish brown sandy loam

C — Pale brownish yellow calcareous loam with chalk fragments

SANTON SERIES (sN)

Fig. 6 Breckland Soils - profile morphology (B)

no single profile has been through all stages of develop-
ment.   The sequence is one of increasing depth of de-
calcification from about 20 to 120 cms, increasing acidity
from alkaline to pH values below 4, eluviation of clay
and finally eluviation of colloidal humus.

The soils occur in different positions in the land-
scape, shown in Fig.4.   The Newmarket and Methwold
Series, the shallower calcareous soils, occur only on
slopes.   The Santon Series, the deep acid podzol with
a Bh horizon of colloidal humus, occurs only on flat,
central upland, sites.   The Worlington Series, the
moderately deep to deep acid with a clay enriched Bt
horizon, on the uplands and on slopes.   This general
distribution in the landscape facets is distinct and
simple.   The local distribution within facets is more
complicated.   Fig.7 shows that the drift surface is not
even but undulates regularly.   The undulations have a
vertical magnitude of 25 to at least 100 cms and a
frequency of 7 to 10 metres.   They are an instance of
the well known stripes and polygons pattern formed by
periglacial cryoturbation, and on the slope and upland
facets they reflect directly the local distribution of
soils.   On slopes the shallow calcareous Methwold and
Newmarket Series occur on the crests of the drift
undulations and the moderately deep acid Worlington
with the clay accumulation at the drift surface, over
the depressions.   On uplands on central sites with
polygons, Worlington soils occur on crests and the
Santon Series, the humus podzol, can be found in
depressions.   The local soil patterns affect plant growth.
Fig. 7 shows _Calluna_ stripes in _Agrostis-Festuca_ Grass-
land, the acidophyllous _Calluna_ on Worlington soils in
depressions, and calcicolous grass heath on Methwold
and Newmarket soils on crests.   Similar patterns
are reflected in crop growth on arable land.

In this landscape the boundaries on maps at the
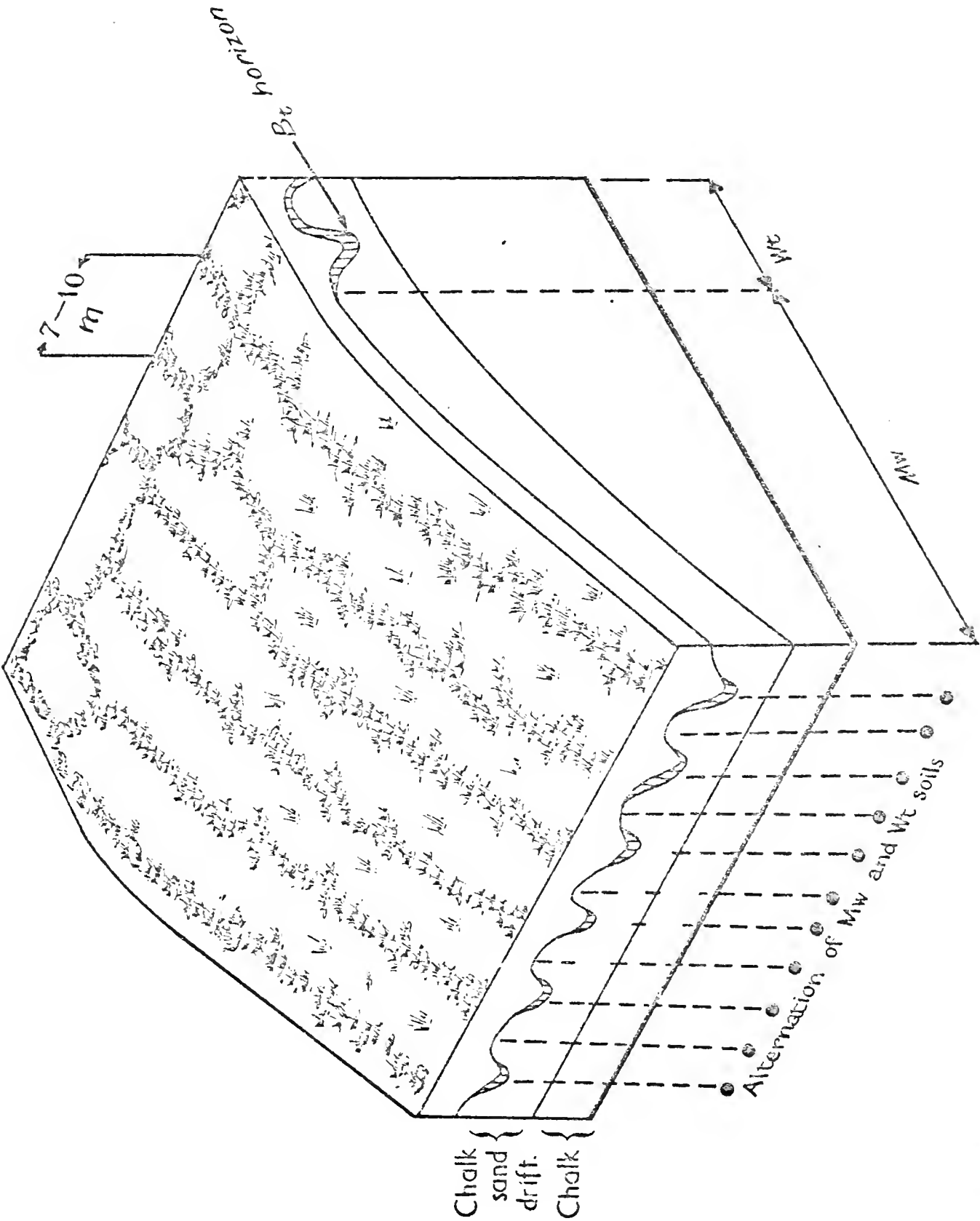$2\frac{1}{2}$ inch scale delineate, in general, only the landscape

Bt horizon

7—10 m

Wt

Mw

Chalk } sand drift. Chalk {

Alternation of Mw and Wt soils

Fig. 7   Breckland Soils – local distribution

facets; uplands with Worlington soils, or a Worlington/
Santon compound unit, and slopes with compound mapping
units of the Methwold, or Newmarket with Worlington soils.
Variation within facets is accounted for by compound
mapping units.

Points of particular interest in interpreting this
soil pattern are firstly, the uniformity of the environ-
ment with regard to features such as parent material and
drainage condition, variations in which elsewhere largely
determine distribution, and secondly, the distinct assoc-
iation of stages in the pedogenic sequence with landscape
position. These allow a geomorphological interpretation
of each surface. The deep soils on the flat uplands
represent, at least in part, weathering during the
Ipswichian interglacial. Slope sites are thought to
have been differentiated during the periglacial conditions
of the last glaciation by solifluction of weathered
surface horizons. The occurrence of stripes rather
than polygons confirms this, and the coarse stony
material lining the wider, dry valley floors is the
product. An interpretation is shown in Fig.8.

Beccles Boulder Clay Soil Pattern

Sheet TM49 (Beccles) lies astride the lower reaches
of the River Waveney where the Boulder Clay plateau,
forming most of the surface in central East Anglia,
is dissected into two additional landscape facets, the
broad infilled valley floor of the Waveney floodplain,
and between this and the plateau, a belt of lowland
(Fig. 9). The plateau at 75 to 110 feet O.D. is flat
or gently sloping. The floodplain, apart from a few
low meandering micro-ridges which represent roddons or
old stream channels, is a flat surface at about sea
level. The lowlands between 0 and 75 feet O.D. are
largely a weakly dissected terrace whose main surface
lies between 25 and 40 feet.

The upland Boulder Clay has small chalk stones and
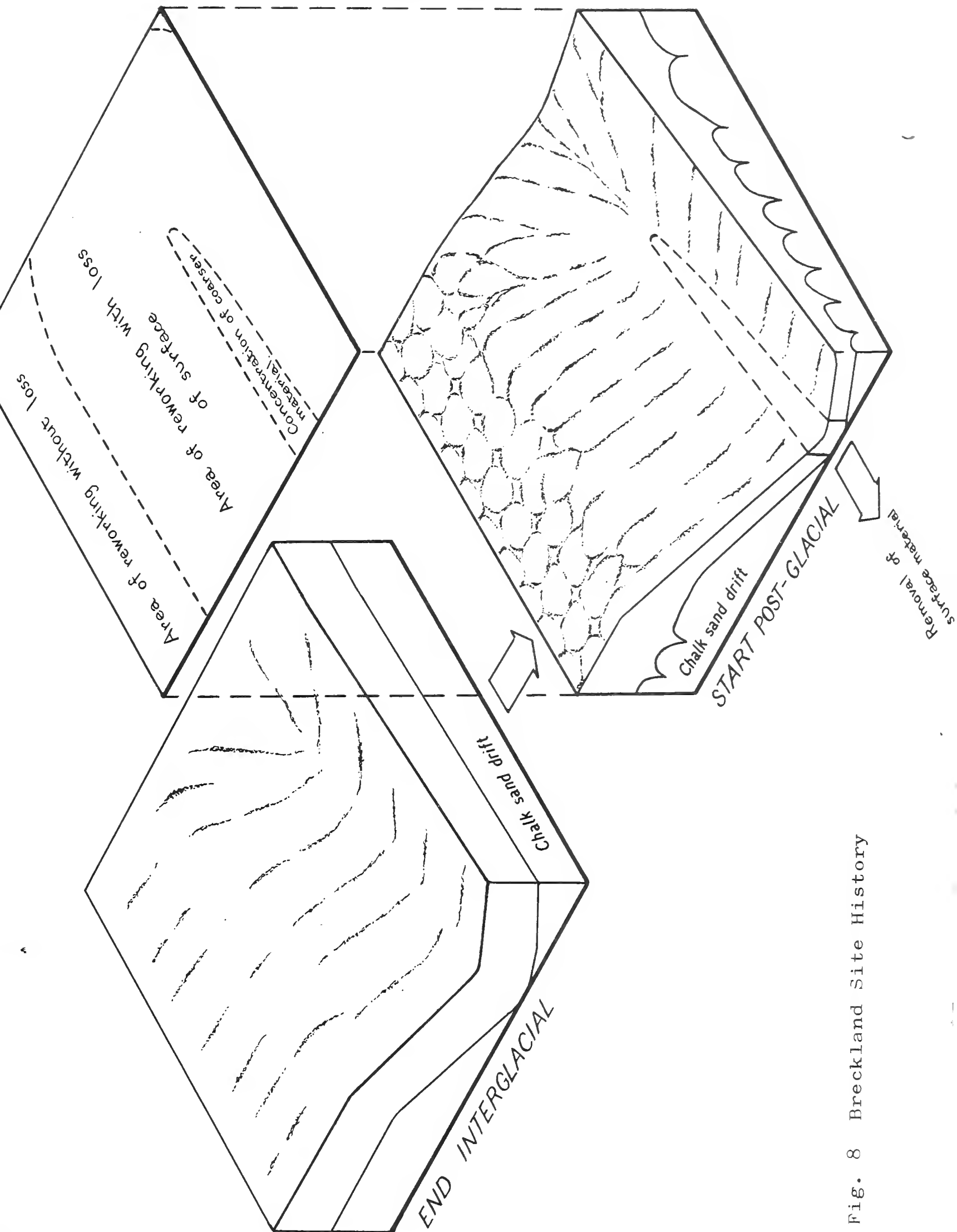is covered on central upland sites by thin Sands and
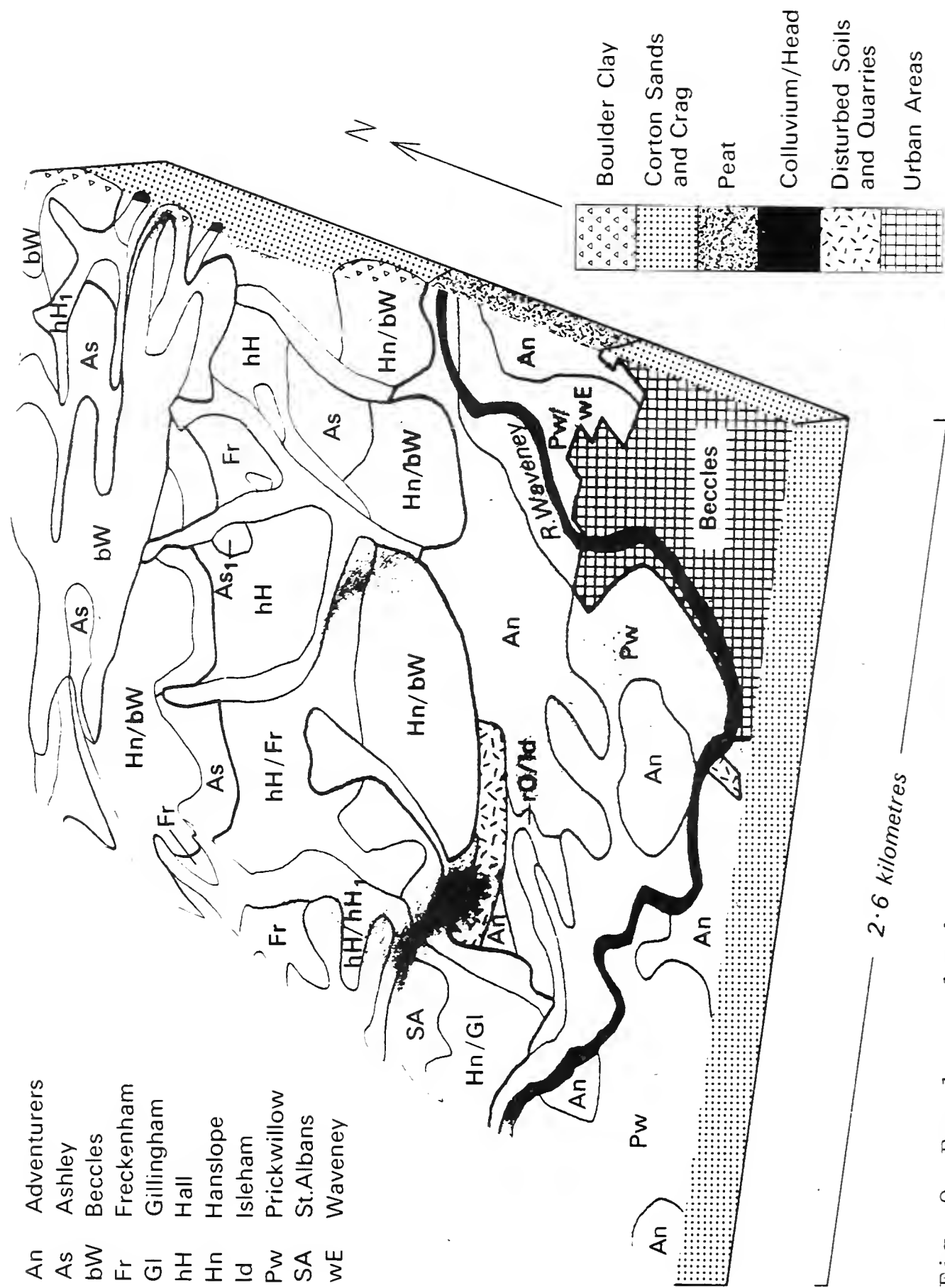
Fig. 8   Breckland Site History

W. B. Corbett

An   Adventurers
As   Ashley
bW   Beccles
Fr   Freckenham
Gl   Gillingham
hH   Hall
Hn   Hanslope
Id   Isleham
Pw   Prickwillow
SA   St.Albans
wE   Waveney

Boulder Clay

Corton Sands
and Crag

Peat

Colluvium/Head

Disturbed Soils
and Quarries

Urban Areas

2·6 kilometres

Fig. 9   Beccles - landscape and soils

Gravels.   The lowlands are mainly Sands and Gravels, the
Corton Sands and Crag deposits, outcropping from below
the Boulder Clay, the break in slope at the point of out-
crop being the boundary between the two facets.   On
terraces these beds can be capped by Valley Gravels.
The river valley floor is infilled largely by organic
deposits such as brushwood peats or nekron muds.   Down-
stream this is almost completely covered by a raft of
estuarine alluvium of silty clay texture a few metres
thick.   Both alluvium and organic deposits are capped
by a thin skin of sedge-carr peat.

The morphology of the boulder clay soils is given
in Figs. 10 & 11.   They vary from sands to clays and
are moderately well-drained to poorly drained.

Aldeby Series - This soil has six horizons and the lowest,
the II Cg horizon of weathered boulder clay, is often well
below auger depth.   A noticeable feature is the sudden
change from the surface sand to the underlying clay, which
can occur at depths up to 2 metres.   The discontinuity
is shown in the horizon nomenclature by the use of Roman
numerals, the decalcified gleyed clay in the lower profile
being annotated IIBg..

The surface plough layer, the Ap, overlies pale-
coloured sands partly eluviated of iron and designated
Eg.   Horizons of iron accumulation below are classified
Bgfe and above, from lateral seepage across the site, as
Agfe.   The Eg or Bgfe overlies the II Bg horizon.   In
this soil the water table over a period of about four
months between December and April rises spasmodically to
within 25 cms of the surface and for long periods, if not
continually, to within 50 cms.   It is classified as
imperfectly or poorly drained.   The major soil processes
are decalcification and gleying.

Beccles Series - These normally have five horizons but the
lowest, the II Cg horizon, slightly weathered boulder clay,
is seldom within auger depth.   The surface Ap horizon
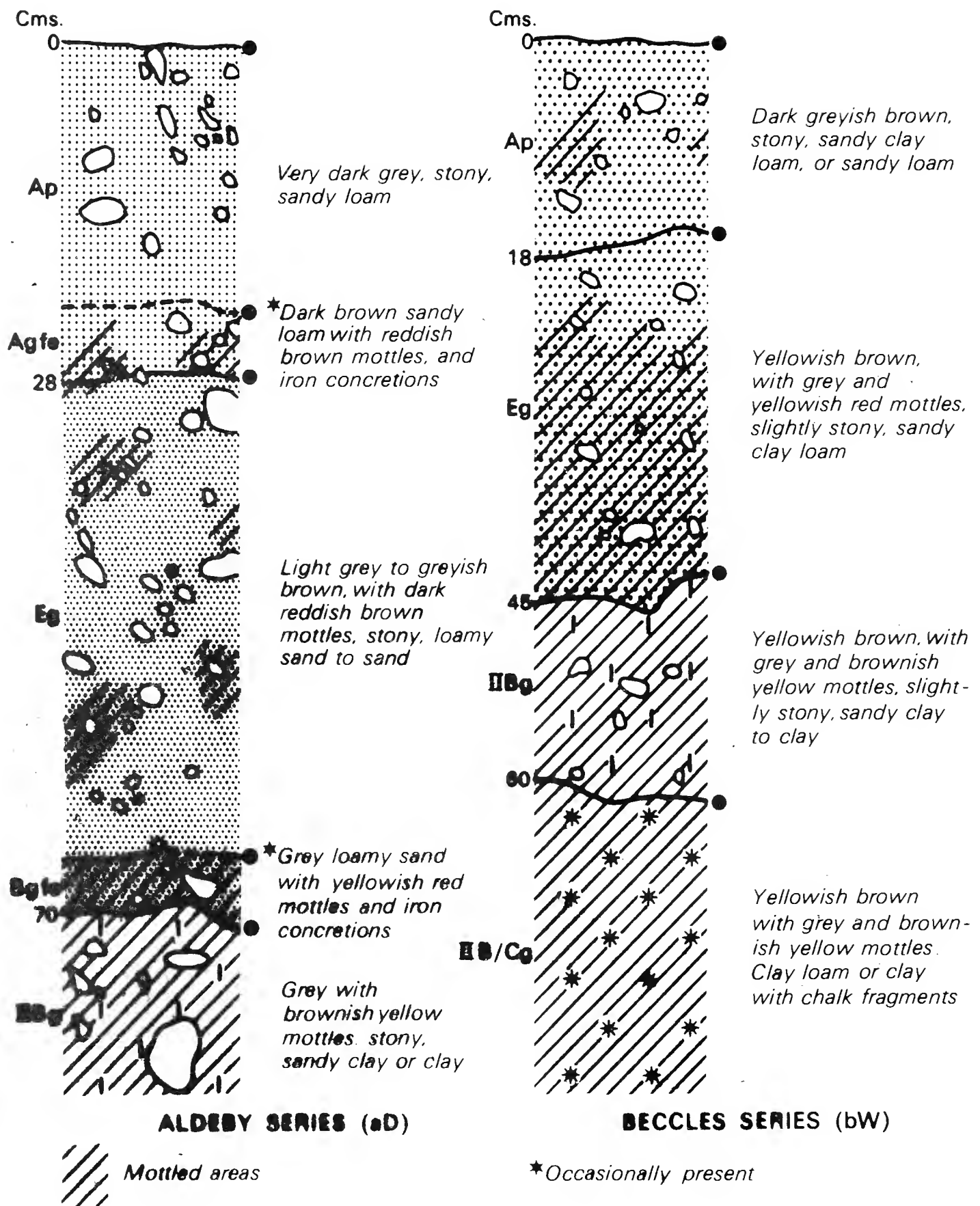has much sand and is a sandy loam or sandy clay loam.

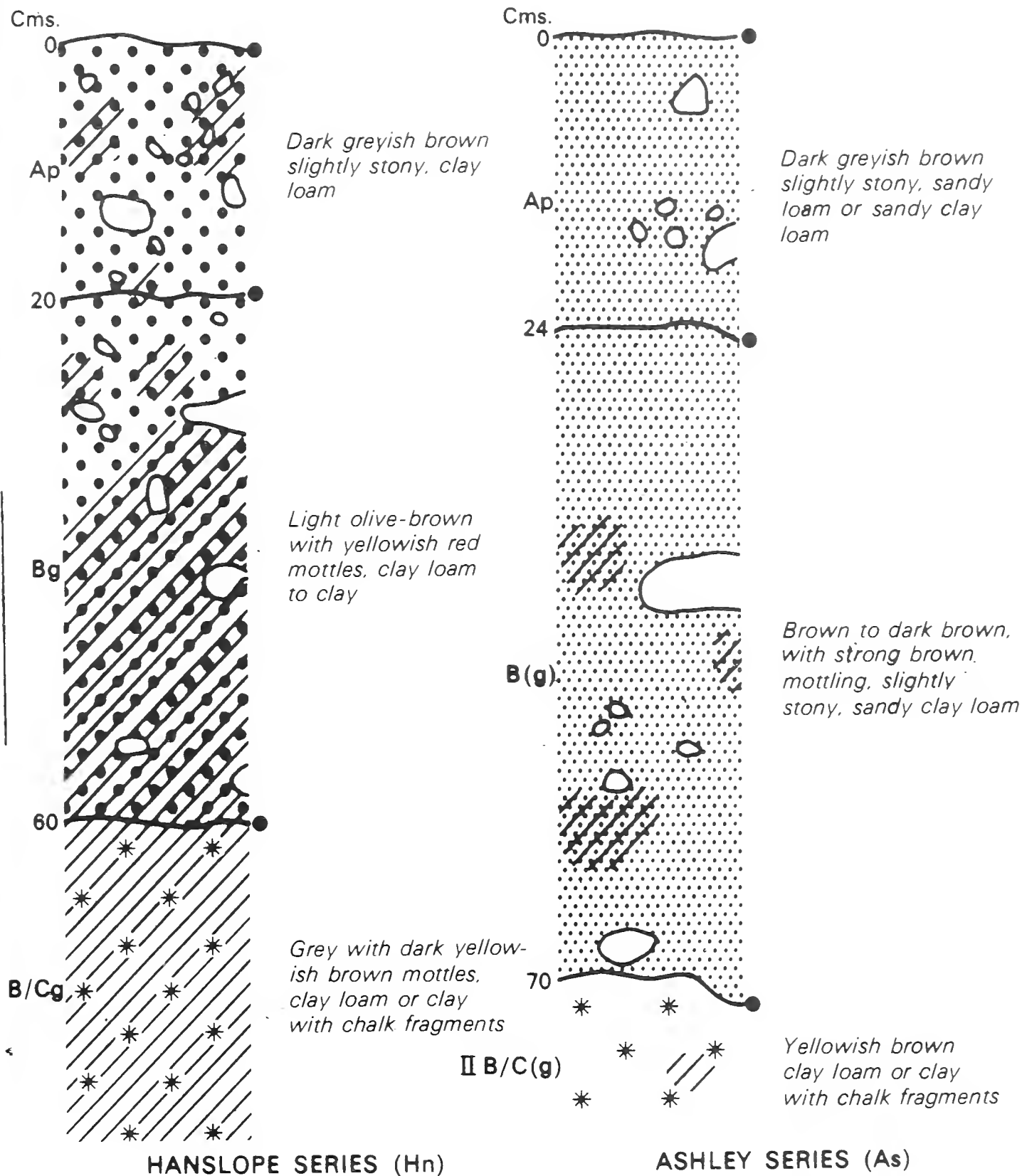Fig. 10   Beccles – soil profile morphology (A)

Cms.

0

Ap

Dark greyish brown slightly stony, clay loam

20

Bg

Light olive-brown with yellowish red mottles, clay loam to clay

60

B/Cg

Grey with dark yellow-ish brown mottles, clay loam or clay with chalk fragments

HANSLOPE SERIES (Hn)

Cms.

0

Ap

24

B(g)

70

II B/C(g)

Dark greyish brown slightly stony, sandy loam or sandy clay loam

Brown to dark brown, with strong brown. mottling, slightly stony, sandy clay loam

Yellowish brown clay loam or clay with chalk fragments

ASHLEY SERIES (As)

Mottled areas

Fig. 11   Beccles - soil profile morphology (B)

The Eg horizon below is a pale-coloured mottled zone
partly leached of iron.   At about 45 cms it passes into
the decalcified mottled boulder clay, the IIBg and at
60 cms to the II B/Cg horizon of mottled grey clay with
chalk stones.   The water regime is similar to that in the
Aldeby series, but Beccles soils can be managed more
efficiently, tile drains and ditches keeping the water
table to below 50 cms.   It is classified as imperfectly
and poorly drained.   The main soil processes are
decalcification and gleying.

Hanslope Series - There are commonly four horizons but the
Cg horizon of unweathered boulder clay, is well below
auger depth.   Deep borings show mottling on structural
faces to below 3 metres.   The surface horizon, the Ap is
a clay loam or sandy clay, and much less sandy than in the
Aldeby, Beccles or Ashley series.   Below this is an olive
coloured, mottled, decalcified well-structured clay or
clay loam, the Bg horizon, changing at about 60 cms to a
grey, mottled, clay with chalk stones, the B/Cg.   The
soil is apparently less affected by the rise in the winter
water table than those described earlier, the gently sloping
site and the better structured subsoil allowing lateral
seepage so that the water table seldom rises to within
50 cms of the surface.   Tile draining and moling are
effective and the soil is moderately well drained or
imperfectly drained.   The main soil-forming processes are
decalcification and gleying.

Ashley Series - This soil, like the Aldeby and the Beccles,
has a textural discontinuity, and three horizons can be
recognised.   The plough layer, the Ap, is over a slightly
mottled decalcified sandy loam or sandy clay loam, the
B(g).   Below about 70 cms is slightly mottled slight
weathered boulder clay, the IIB/C(g) horizon.   There is,
apparently, no winter water table.   On sites with Ashley
soils the boulder clay is a shallow cap only 1 to 2 metres
deep over permeable sands and gravels, and the clay is
apparently sufficiently fissured to allow vertical seepage

of drainage water.   The soil is moderately well drained.
The soil-forming processes are predominantly decalcification
with slight gleying.

     These four soils are presented in Fig. 10 in the order
in which they occur from the centre to the edge of the
boulder clay uplands.   Differentiating features are surface
sand in the Aldeby, the absence of this in the Hanslope,
and the mixture of sand with the clayey substrata in the
upper horizons of the Beccles and Ashley.   The Ashley
series with permeable substrata and no winter water table
is moderately well drained.   In the other three soils,
the thickness of the boulder clay is sufficient to form an
impermeable substratum, preventing vertical seepage and
supporting a winter water table.   In the Hanslope, however,
the effect is ameliorated by lateral seepage on sloping
sites through the well-structured subsoil.   In contrast
to the Breckland, these differentiating features are here
due to variations in lithology rather than the soil-
forming process, which is similar for three of the soils.

     The general distribution of three of the soils in the
upland landscape facet is shown in Fig. 9, the area just
north of Beccles.   The sequence from central to perimeter
sites on the uplands is Beccles, Hanslope, and Ashley series.
Aldeby soils occur slightly higher to the north.   As in
the Brecklands, local distribution is more complex, and Fig.
12 shows the scale of variation.   The site is a boulder
clay crest overlaid by shallow surface sands and gravels.
Trench A is on the flat crest, B down slope and C across
the slope.   It is worth comparing these somewhat regular
contortions with those in the Breckland stripes and
polygons.   Fig.13, from Trench C, shows Aldeby and
Beccles soils adjoining, Beccles soils occurring where the
boulder clay is almost immediately below the plough layer.
Such a site is mapped as a compound unit of Aldeby and
Beccles.   Both the magnitude and the frequency of boulder
clay contortions is of the order of two metres.   This is
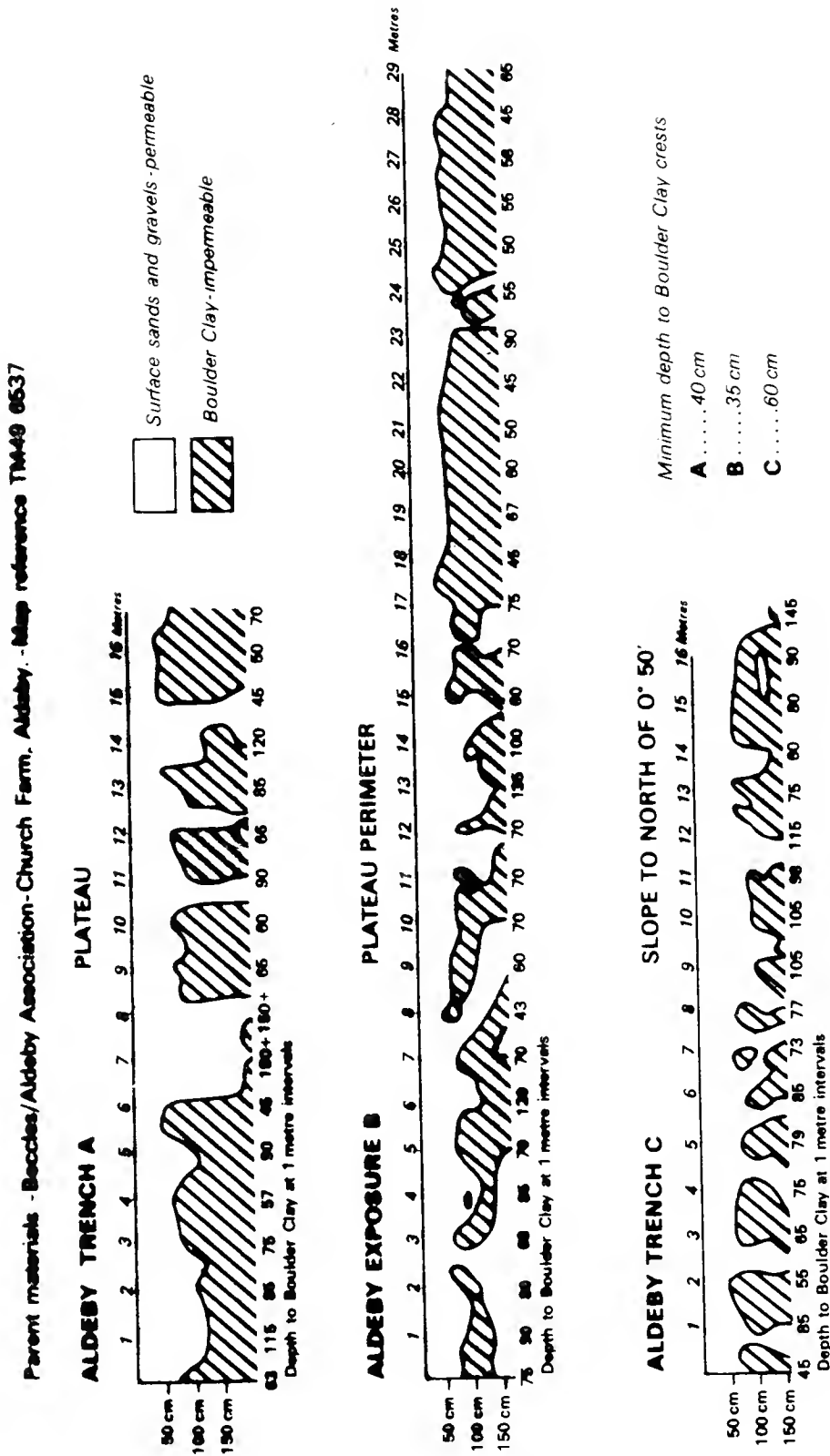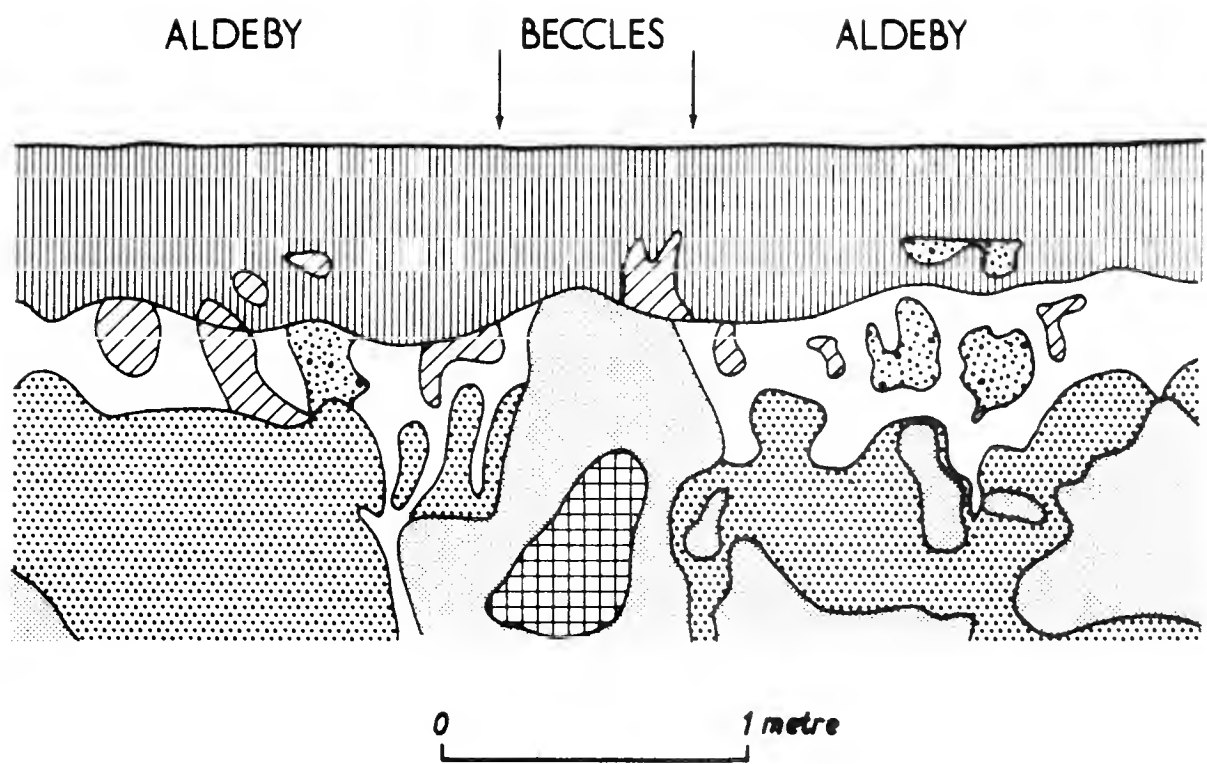extreme, and a more subdued variation, with a vertical

W. B. Corbett

Fig. 12   Beccles – distribution of surface gravels and boulder clay

ALDEBY   BECCLES   ALDEBY

0   1 metre

Dark coloured humose surface horizon

Zones with concentrations of iron concretions

Lumps of weakly to strongly cemented iron pan

Iron enriched, reddish sandy loam to sandy clay

Weathered non - calcareous Boulder Clay
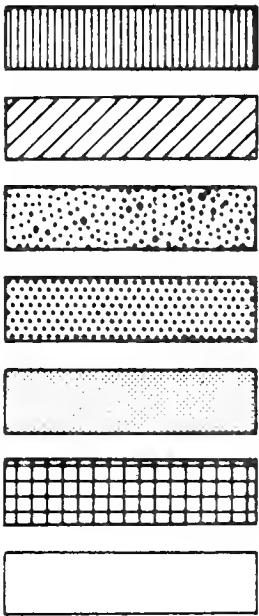
Chalky Boulder Clay

Bleached sand

Fig. 13 Beccles - soil pattern in Beccles/Aldeby unit

magnitude of about 10 cms, and a frequency of about two
metres occurs on sites where shallower soils with a clay
loam or sandy clay plough layer (Hanslope series) alternate
with soils with surface textures of sandy loam or sandy
clay loam over depressions in the boulder clay (Beccles
series).

Mapping units on the plateau, shown in Fig.9, are
compounded of Beccles and Aldeby soils on central sites,
the Beccles series over most of the plateau, a compound
unit of the Beccles and Hanslope towards and at the
perimeter, and Ashley series on the crest of projecting
spurs.

This pattern can be related to three related factors:
the distribution of surface sands, apparently eroded from
all but central plateau sites, and particularly from
gently sloping sites towards the plateau perimeter;
vertical seepage through the boulder clay where it thins
out at the plateau perimeter, and frost heaving with the
maximum effect where the textural contrast is greatest.
Changes in the first two factors are on a scale of several
hundred metres and are seen on 1:25,000 scale maps in the
sequence of mapping units across the plateau. The short
range scale of the third factor can only be indicated by
compound mapping units.

Cromer Ridge and Boulder Clay Soil Patterns

Fig. 14 shows a north-south section from the ridge
crest to boulder clay lowland to the south, the boundary
between the two landscapes occurring at Matlask. On
the ridge the substrata are predominantly Pleistocene
Sands and Gravels, and in the southern lowlands a brown
non-calcareous boulder clay morphologically resembling
the Norwich Brickearth. In both landscapes these
materials are covered by thin loamy drift probably of
aeolian origin. The textures of all three materials are
shown in Fig.15: the gravels have less than 10 per cent
clay and less than 15 per cent silt; the brown non-
calcareous boulder clay, a clay content between 15 and
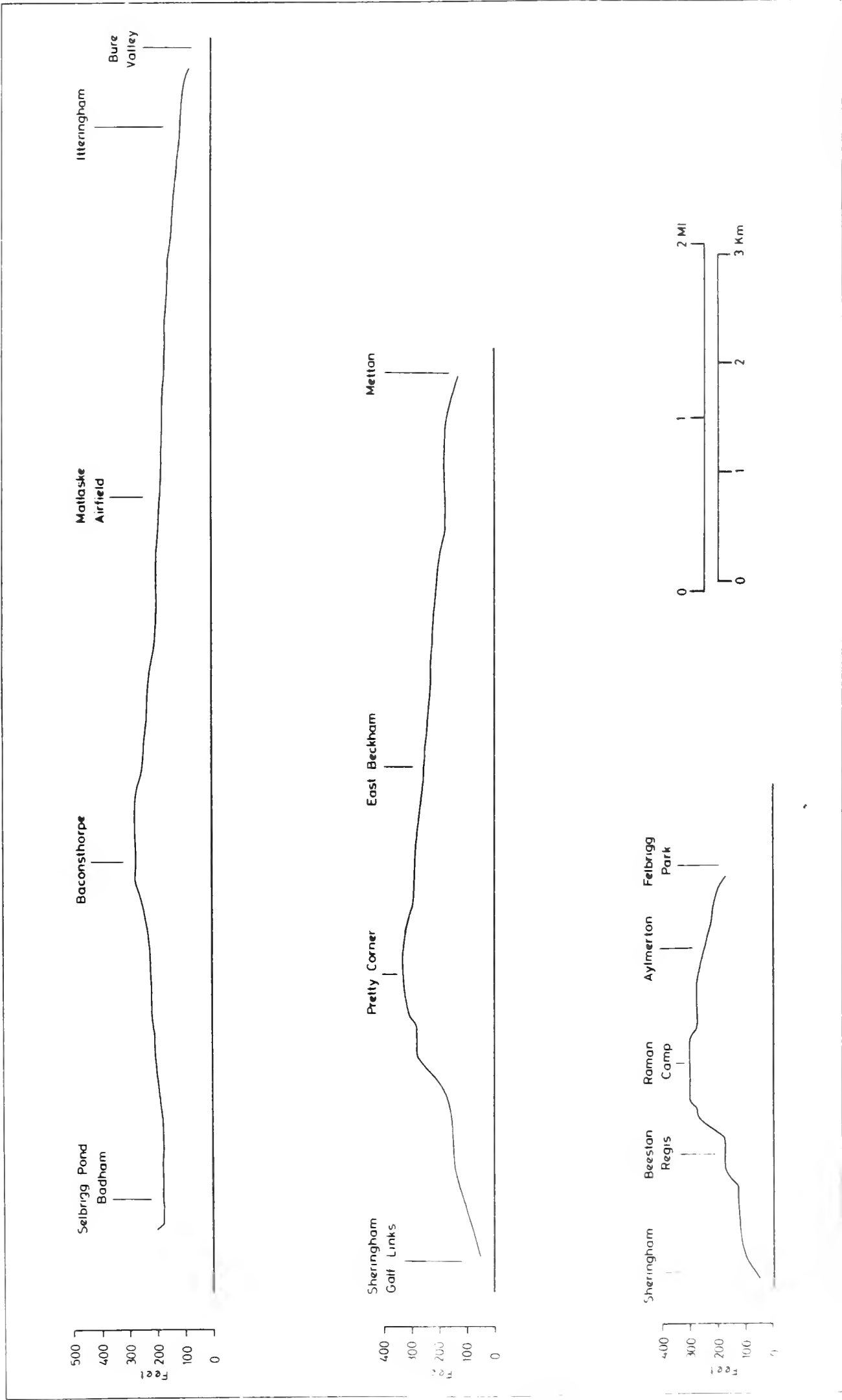
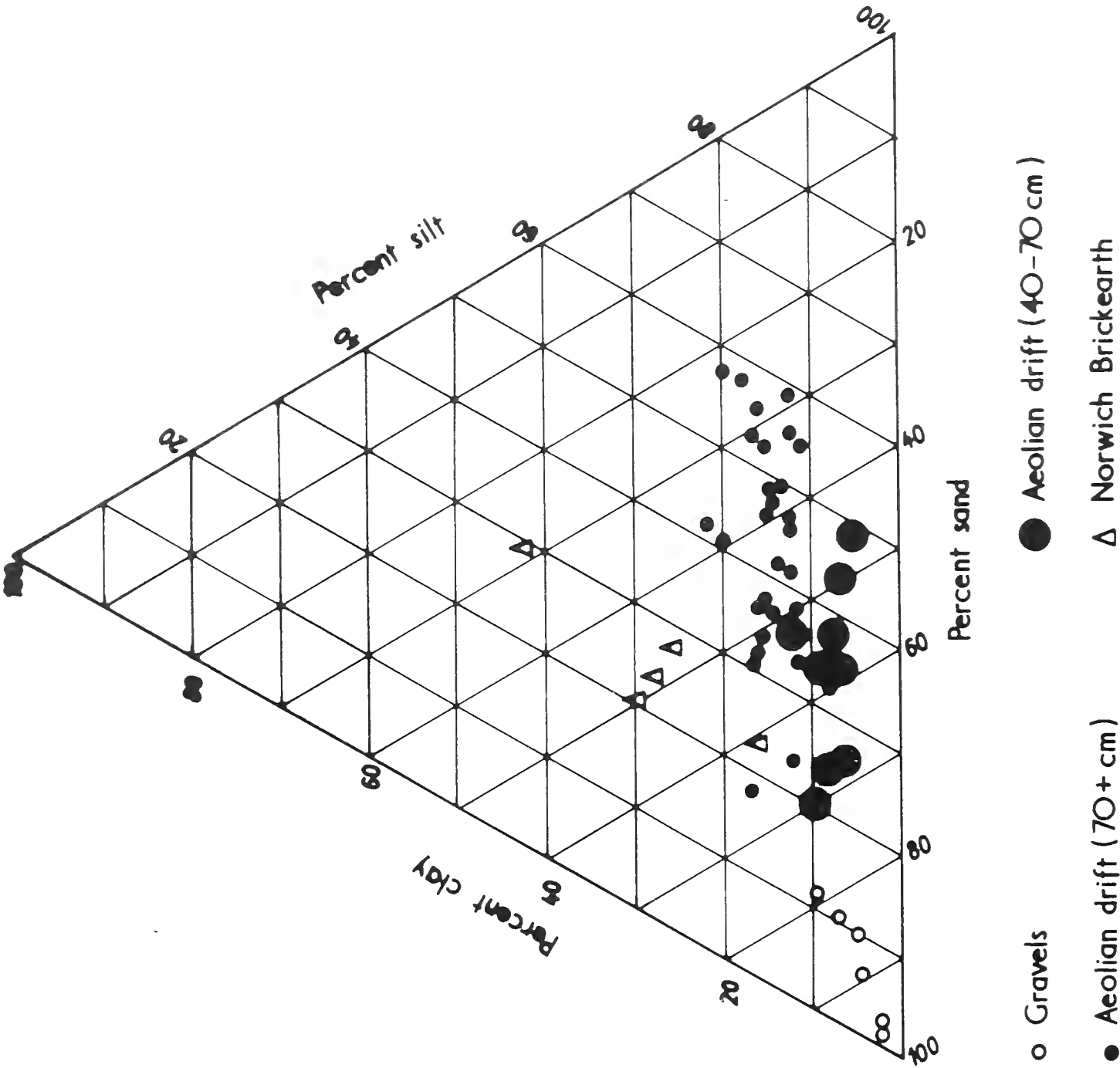Fig. 14   Cromer Ridge – relief sections

Fig. 15 Cromer Ridge - mechanical composition of Drifts

30 per cent, and a silt content between 20 and 30 per cent;
and the covering aeolian drift less than 20 per cent clay
and 20 to 60 per cent silt.   The texture of this covering
is related to its thickness.   Thin deposits contain less
than 10 per cent clay and less than 50 per cent silt, and
thicker deposits 10 to 20 per cent clay and up to 60 per
cent silt.

        Fig. 16 shows their distribution in the landscape.
On the ridge, aeolian drift is absent from the steepest
slopes with southern and western aspects.   Shallow
deposits, 40 to 70 cms thick, occur on flat crests, and
deposits more than 70 cms thick on valley floors and on
the gentle lower slopes with northern and eastern aspects.
On Boulder Clay Lowlands, shown in Fig.17, the pattern is
broadly similar.   Additional facets are shallow sand
and gravel caps on interfluve crests, terraces and peat-
filled floodplains.   Excluding these latter sites all soils
both on the Cromer Ridge and in the Lowlands to the south
are well drained or moderately well drained and are Brown
Earths.

        On bare ground in Spring the pattern on the Cromer
Ridge is sometimes shown by the colours of the surface
soil, darker tones indicating moister and deeper more
silty aeolian drift with fewer stones.   Later in the sea-
son the pattern is reflected by crop growth, in dry years
the best growth occurring on valley floors with poorer
growth on slopes.   In wet years the growth pattern is
reversed, cereal yields being higher on slopes.

Discussion

        The soils and soil patterns described illustrate the
two purposes of soil survey; classification and mapping.
The basic unit in classification, the soil series, is de-
fined by the nature and intensity of the soil-forming
process, the texture of the parent material and the water
regime.   On the Breckland drift, with uniform parent
material and water regime the series can be regarded as
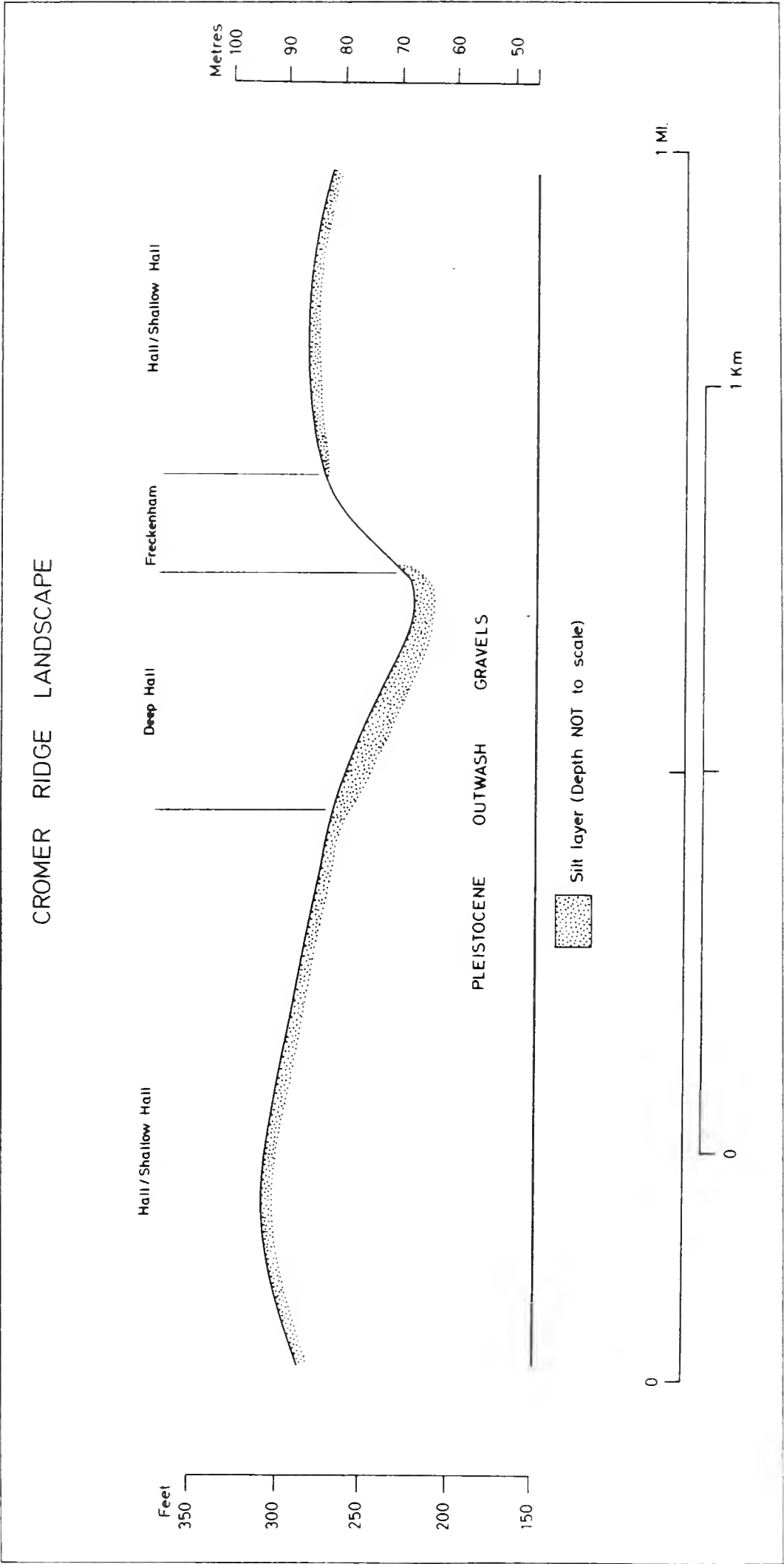consecutive stages in a theoretical soil development

Fig. 16 Cromer Ridge - soil pattern

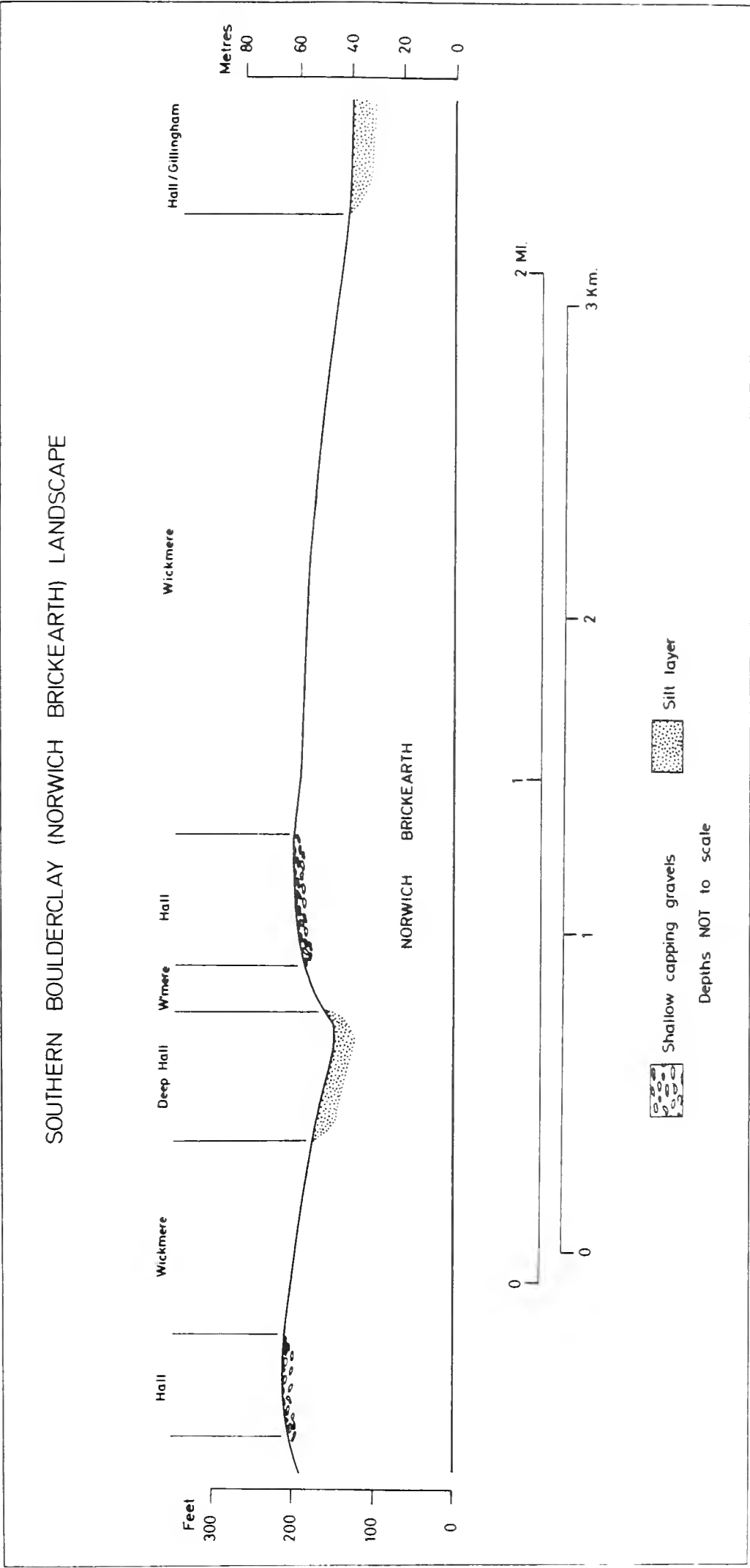SOUTHERN BOULDERCLAY (NORWICH BRICKEARTH) LANDSCAPE

Fig. 17   Boulder Clay Lowlands - soil pattern

sequence.   On the Cromer Ridge where the water regime
and soils-forming processes do not vary, series are
characterized by varying depths of aeolian drift over
gravels or boulder clay.   At Beccles, series on Boulder
Clay are differentiated by depths and texture of surface
drift, in this case sands and gravels, with the additional
factor of a variable water regime due to permeability of
the boulder clay below and lateral seepage.   Thus in
establishing a classification for a locality distinctions
are made according to the local importance of one other
of the three components.

The distribution of soils in the three areas shows
that pattern occurs at different scales.   Small-scale
variation such as the sand and gravel-filled pockets in
the boulder clay surface round Beccles or on the
Breckland stripes are recorded on $2\frac{1}{2}$ inch maps by compound
units.   Large-scale variation, occurring across
individual landscape facets, at intervals of several hundred
metres, are shown by the sequence of mapping units, the
Aldeby, Beccles, Hanslope and Ashley sequence at Beccles
and the Worlington unit and Worlington/Santon compound
sequence unit on the Breckland uplands.   A still larger
scale pattern is seen in the sequence of facets in any
landscape, and the largest in the landscapes themselves.
Examples in East Anglia of such landscapes are the Fens,
the Chalk Scarp, the Brecklands, the mid-Anglia Boulder
Clay Plateau, and the Cromer Ridge.

A 1:25,000 sheet is mapped in two stages:
reconnaissance when soil to landscape relationships are
established, a taxonomic legend set up, and mapping units
chosen; and detailed mapping, when boundaries between
units are located.   Such boundaries can be visually
associated with relief features or found by a regular
grid of auger borings, which at the 1:25,000 scale are
often at 200 metre intervals.   The value of units thus
mapped stems from the principles of soil distribution
established by reconnaissance.   In practice the principles,

and consequently the mapping units and boundaries, are
often further developed during the detailed stage.   A
procedure used earlier for reconnaissance in this region
employed transects across relief features with a sampling
interval of less than 200 metres.   On sheet TM31 (Horning),
where reconnaissance has just been completed, the sampling
system consisted of 25 major sampling centres spaced
regularly at 2 kilometre intervals, each consisting of
four subsidiary sampling centres at the corners of a
square of 200 metre side, each in turn having four
sampling points at the corners of a square of 20 metre
side.   In such 'nested' sampling the 2 kilometre interval
is designed to identify landscape facets, the 200 metre
interval picks out variation within facets and the 20
metre interval establishes local variations like those in
Breckland stripes.   Profile data recorded in this unbiased
way can be treated statistically and sorted into groups
of similar profiles, taxonomic units or individual soil
series.   Series in particular parts of the landscape can
also be grouped into mapping units.

Submitted July 1970

this zone.

These noted are contributed on the chance that the information may be useful in further research on this subject.

Submitted March 1970

TEMPORARY EXPOSURE IN THE DRIFT NEAR CROMER

P. H. BANHAM

Introduction

Excavations in connection with the building of the
Clifton Park housing estate on the Runton Road at Cromer
have revealed an interesting temporary exposure in deform-
ed glacial and glaci-fluvial deposits.   The precise
location is on the northern flank of a small hill (+150'
OD, named Howard's Hill on the 6" map) near the western
boundary of the Urban District of Cromer.   At the moment
the section lies parallel to and within 20 metres of
number 81, Clifton Park (TG 209421).   More houses are to
be built in the immediate vicinity, however, and it is
understood that the exposure will be at least partly
obscured in the near future.

Description of the section

These observations were made at the end of July and
during mid-September 1970.   The exposure (Fig.1) was then
60 metres in length and up to 4 metres in steep to vertical
section.   The succession would seem to be as follows:-

3.	Gravel and Sand	2m (maximum vertical
2.	Yellow Sand	3m thicknesses are
1.	Chalky Till	3m given).

1. The Chalky Till has a small outcrop in the central part
of the section, where its presence is due to disturbances
of the beds.   The larger part of this outcrop consists
of very chalky, white till with few flint pebbles; the
remainder is cream to brown in colour, less chalky, and
contains more numerous erratics, mainly rounded, black
flint pebbles (200 mm and under).   Both these lithologies
may without difficulty be matched within the Contorted
(Marly) Drift and its included chalk rafts exposed in the
nearby and generally lower coastal cliffs.
2. The Yellow Sand is generally coarse and cross-bedded,

."IRON MINERAL GEODES" OF SUFFOLK

H.E.P. SPENCER

In nearly half a century of observations in Suffolk
sands and gravels, inevitably some familiarity is gained
with the varieties of ferruginous concretions, etc.,
which occur with some frequency in most pervious deposits
such as sand and gravel, including the Red Crag.   However
with less experience of Norwich Crag no comment can be made.

An important fact has to be taken into consideration,
which is drawn from archaeological observations, i.e. iron
nails from fourth century Roman villa sites and the clench
nails from ship burials of the dark ages, provide a clue
to the hollow found in a great proportion of the geodes.
In these, it has been found that the original iron, during
the process of oxidation, has migrated outward, concreting
the surrounding matrix of sand or gravel, leaving a hollow
mould in the size and form of the object.

So far as the Red Crag is concerned, as the level of
the sea spread inland, the London Clay, with pyritous
nodules and pyritised wood in large quantities, was eroded
and in some local areas totally destroyed.   Since
the presence of London Clay Crustacea and other fossil
remains which became incorporated with the other derived
materials in the Basement Bed prove this destruction, it
is obvious that other solid objects would similarly be
included in the new formation.   It is also noteworthy
that areas of the Clay were full of fine particles of
pyrites, or marcasite.   This was probably disseminated
throughout at least part of the Crag.   The structure
of the lower part of the Red Crag shows that the beds were
deposited, then removed by currents and re-deposited,
which must have resulted in the redistribution of matter in
the older parts of the formation.

A number of geodes which have been examined, have been
found to contain a yellow powdery residue somewhat similar

in appearance to the residue resulting from the decomposition
of pyritised wood when the iron sulphate is washed away.
This residue has not been analysed, but such analysis should
be illuminating.

Other geodes, not from Crag, are completely hollow
except for column-like structures linking the lower and
upper surfaces, these often are lined with a glossy black
coating resembling a form of pyrolusite.

The Gipping outwash gravels in south east Suffolk
contain a great quantity of derived fragments of Crag
shells and very rarely, bits of sub-Crag bones, a result
of the destruction of an area of Red Crag northward of
the mapped limit.   Some of the geodes could possibly be
derived from that Crag.

The suite of erratic rocks, notably at Creeting St.
Mary in the Gipping Valley, is similar in both the out-
wash gravel and the overlying Gipping Till.   Boulders of
basaltic rocks with spheroidal weathering have been
obtained from both, others are Jurassic limestones from
Lincolnshire and garnetiferous schist from Scotland.
Amongst the Jurassic materials are masses of limonitic
material full of moulds of shells.

During the nineteen-twenties a Crag pit on Bixley
Heath, Ipswich, had an interesting lenticle in the
section below 8 to 10 feet of decalcified Red Crag with
stalactite-like concretions formed around roots with
moulds of shell fragments.   The lenticle was a solid
mass of limonitic rock full of moulds of large bivalves.

At no time has any concretion been observed which
had the appearance of having been formed by the concen-
tration of ferruginous matter to form a concretion.

In the Westleton Marine Shingle Beds at Holton,
below the water table, there is a pyritised zone with
shells and impregnated fossil wood with some bones and
teeth of Villafranchian fauna.   From the evidence at
this site it seems probable that lowering of the water
table would eventually result in the limonitisation of

the laminae dipping E to NE at up to 20° where undisturbed.

3. The Gravel and Sand overlies the Yellow Sand sometimes
with evidence of marked channelling.   Flint boulders of
"cannon-shot" type are common.

The entire section exhibits minor undulations and
other disturbances, although the only significant deformation
involves the Chalky Till and those parts of the other beds
which are immediately adjacent.   A horst-like mass of
Chalky Till has been emplaced into the overlying Yellow
Sands.   The western till/sand contact is deformed about
open folds of very variable plunge, although the largest
of these plunges approximately west at 5°, and has a
nearly horizontal axial plane.   Despite this folding it
can be seen that the bedding of the Yellow Sands is approx-
imately co-planar with the surface of the Chalky Till.
This suggests that the original, sedimentary, till/sand
junction is here little disturbed.

The eastern side of the Chalky Till mass, by contrast,
shows a nearly vertical, smooth, planar contact with the
Yellow Sands which have suffered local dragfolding.   The
overall impression is that of a fractured diapir and/or a
minor upthrust mass of till.

That such upward emplacements of till may be common
in this area is indicated by the apparently haphazard and
rapid alternation of sand and chalky till demonstrated and
described to me by the men who had dug the foundations of
the houses within half a kilometre to the north (i.e.
approximately down to the 100' contour).

Discussion

There would seem to be little doubt that Chalky Till
is a disturbed portion of the local chalky variety of the
Contorted (Marly) Drift.   Further, on the grounds of
general lithological similarity and the geomorphological
continuity of Howard's Hill with the main "Cromer Ridge"
to the south, the Yellow Sands and Gravel and Sand can
be accepted as part of the variously named (Cromer) Ridge

or Briton's Lane Gravels.

The well-known Briton's Lane pit is within 4 kms to the west of Howards Hill and it is of some interest that it, too, shows chalky till upthrust into the sands and gravels (immediately south of the pit offices and works).

The full implications of all the available evidence can not be discussed here. In brief, the Howard's Hill exposure confirms the conclusion that at least one period of deformation, probably glacially initiated, but not necessarily glacial tectonic, occurred after the deposition of the Ridge Gravels.
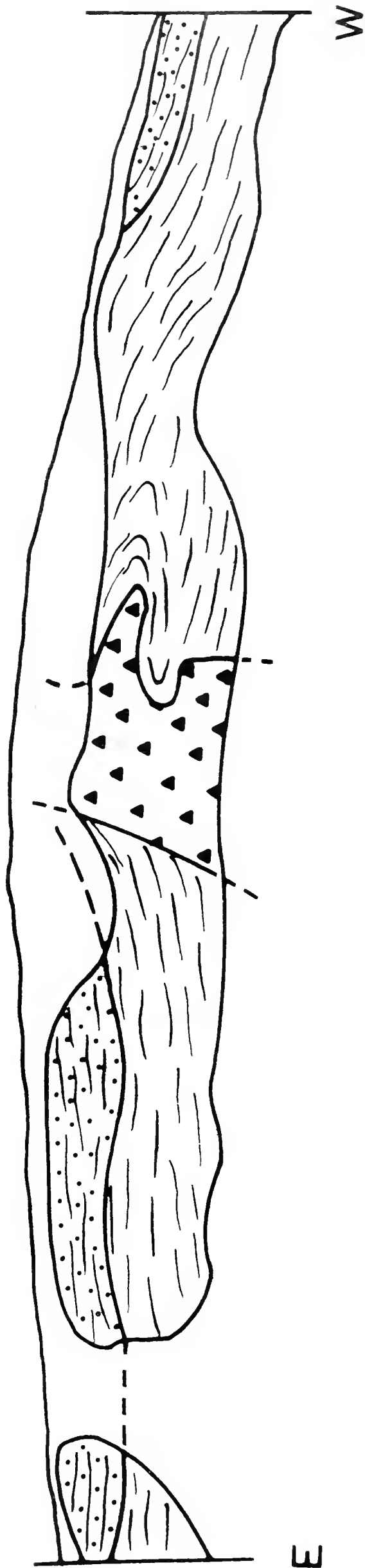
Submitted October 1970

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Fig. 1

REPORT OF A FIELD MEETING IN BRECKLAND, 20 SEPTEMBER 1970

C.E. RANSON

The meeting began at East Wretham Heath (TL 912884), a Reserve of the Norfolk Naturalists' Trust.

A description was given of the Great Ouse River Authority's ground water pilot scheme. This is being undertaken to see if it is possible to abstract water from the Chalk aquifer in such a way that percolation from rainfall and other surface water will provide continuous replenishment of the Chalk aquifer after the water table in the chalk has been lowered 7m by pumping.

Since this is a pilot scheme, the whole exercise is being closely monitored. The area where water is being extracted is confined to about 70 km^2 in the parishes of Great Hockham, Bridgham, East Harling, Quidenham and Shropham, and within the catchment of the River Thet. Observation boreholes, river and mere gauges and meteorological stations have been established to record the changes caused by the abstraction and to relate them to meteorological conditions. A similar series of observations is being made in an area of comparable size centred about 8 km to the north west and including parts of the parishes of Tottington, Thompson, Merton, Stamford, Stow Bedon, Sturston and Buckenham Tofts in the catchment area of the River Wissey.

The experiment is to run for seven years. If it is successful, it is possible that the practice will be extended to other parts of the Chalk in the River Authority's area.

The pilot scheme has required the sinking of a great number of boreholes to the Chalk. The new information on the thickness and nature of the drift overlying the Chalk has yet to be interpreted fully, but it is apparent that there is a great deal more boulder clay in thickness and extent than was formerly supposed.

East Wretham Heath lies between the pilot area and the control area. A borehole put down in 1968 at TL 908884 on the higher land between Langmere and Ringmere, as a supplementary observation well to give information on the water levels of the two meres, showed the following succession:

Lithology	Thickness	Depth of base from surface
Sandy soil	0.35m	0.35m
Sandy subsoil	0.40m	0.75m
A mixture of sand, chalk, pebble and chalk clay becoming gravelly toward the base: Chalk Boulder Clay	c. 15m	c. 16m
Chalk	c. 9m	c. 25m

Water was found at 6m down from the surface and also in the Chalk. The upper water level was approximately the same as the level in the meres.

This borehole showed that in spite of the observed correlation between water levels in these meres and the Chalk (Jones & Lewis 1941) there is a need to reconsider the nature of this relationship. As the pilot scheme progresses, more information should become available on the shape of the boulder clay surface and the connection between rainfall and the water tables of the boulder clay and the Chalk.

As a result of the recent excavations of trenches for pipe lines across the Breck, a number of sand-filled depressions in the boulder clay have been noted. These depressions have the approximate lateral dimensions of some of the smaller meres, though their vertical extent is not known. They appear to be periglacial features and it maybe that some of the meres are of similar origin; but detailed work would be necessary to substantiate this or any other observation on the origin of the meres.

The second feature visited was the area of stone stripes on Thetford Heath National Nature Reserve.

Fortunately part of the Heath near the road at TL 849796 has had its topsoil removed so that it is possible to see clearly the parallel rows of stone and chalk alternating with rows of sand.   Where the topsoil has not been removed the rows of stone and chalk support a grassy vegetation and the deeper, less calcareous, sandy soil carries a strong growth of heather (Calluna vulgaris), thus making it possible to detect striping on vegetated heath.

This convenient example is one of many throughout the Breckland and these, with other types of patterned ground due to periglacial conditions, are described in Watt (1955), Watt, Perrin and West (1966), Williams (1964) and West (1968, chapter 5).

The third visit was to the High Lodge site, Mildenhall (TL 738754) which is owned by the Forestry Commission but leased to the Suffolk Trust for Nature Conservation.   This former gravel pit has been well known for its Palaeolithic implements for over 100 years.   It was re-excavated by G. de G. Sieveking of the British Museum during the last decade and the site has now been systematically recorded and the deeper holes filled in.   The present exposures show the upper part of the sequence: a thin layer of chalky clay, underlain by sands and gravels and chalky gravels, lying on a series of sands, silts and clays, which in turn lie on a calcareous boulder clay.   Many Palaeolithic implements, especially handaxes, came from the upper part of the series of sands, silts and clays.   At the present time the author has no detailed information on the outcome of the archaeo-logical and geological studies made at the site.

The fourth visit was to Mr. and Mrs. Rumbelow's disused chalk pit at West Row (TL 681753).   Here the Lower Chalk shows the development of a pink horizon, a half to one metre thick.   The intensity of the coloration varies vertically and horizontally.   One fossil brachiopod and a probable trace fossil were found.   This section needs a detailed description.

The final visit to the Lark Valley between Barton Mills and Lackford demonstrated the series of partially active sand dunes on either side of the A1101 from TL 740740 to TL 770733 and the gravels on Rampart Field, West Stow (TL 787716).   Funnell (1955) has described the geology of this and surrounding areas in some detail.

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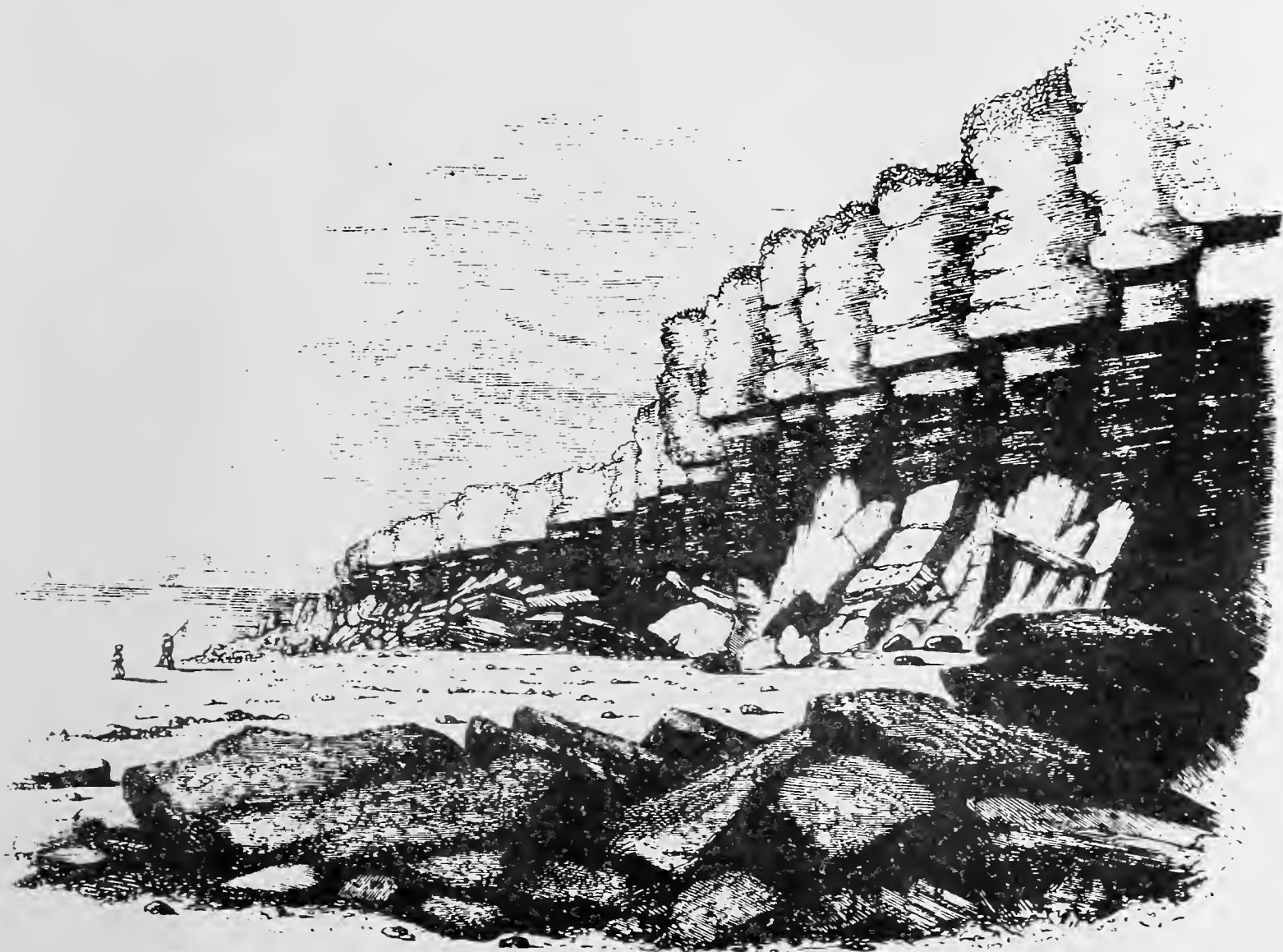
BULLETIN OF THE GEOLOGICAL SOCIETY OF NORFOLK

No. 20

CONTENTS INCLUDE:

EDITORIAL

In this, the second issue of the Bulletin in its new
format, we have articles on the origin of the North Sea,
Geological education, and the Chalk in Suffolk.

The growth of Geology as an academic subject, in all
types of educational establishment, was remarked on in
the recent talk by Mr. Colin Ranson ("Geology for Young
and Old" - Castle Museum, March 25, 1971), and our present
contributor, Mr. Hywel Evans, who lectures at the Norfolk
College of Arts and Technology, King's Lynn, outlines
methods and progress there. It is hoped in future issues
to publish articles on other aspects of Geology and
education.

Bulletin No.21 will be issued in the Spring of 1972.
Contributions should be sent to me as soon as possible, and
no later than January 31, 1972.

Will contributors please note that manuscripts are
acceptable in legible handwriting, although typewritten
copy is preferred. Illustrations intended for reproduction
without re-drawing should be executed in fine, dense black
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                                                R.S.J.

THE ORIGIN OF THE NORTH SEA

(a summary of the Presidential Address for 1969,
delivered January 15, 1970)

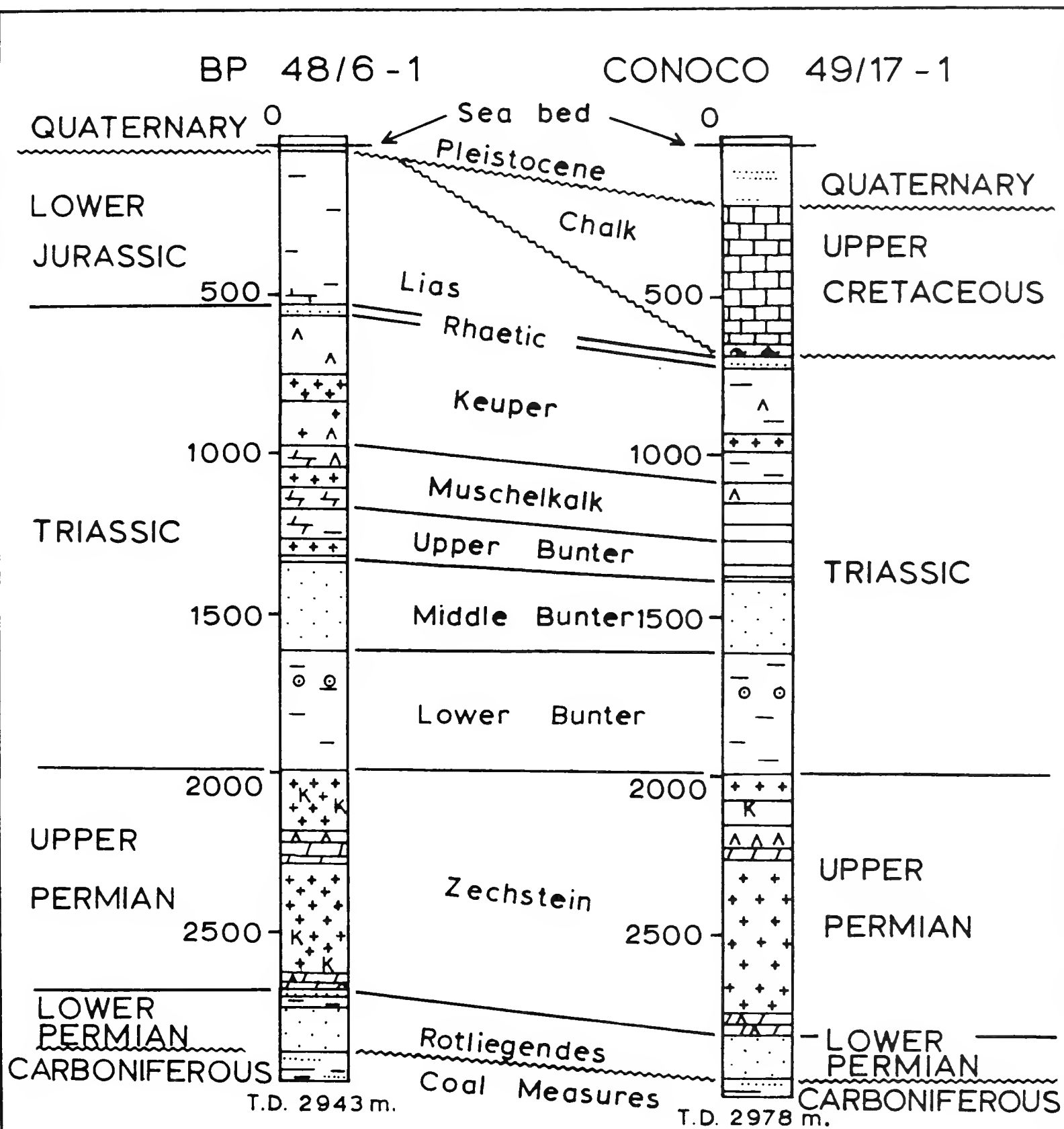B. M. FUNNELL*

Introduction

- The North Sea is a shallow epicontinental sea
bordering the North Atlantic ocean, with which it connects
broadly to the north, and narrowly to the south via the
Straits of Dover. Over most of its southern half it is
less than 50m deep, and even in its northern part does
not generally exceed 200m in depth.

The North Sea occupies a structural basin known as the
North Sea Basin, which has existed in some form or other,
and contained shallow seas of one form or another, for some
270 million years, i.e. from the Permian period onwards.
During this time nearly 5,000m of sediment have accumulated
in places in the Basin, compared with which the depth of
the present sea is insignificant. At no time has the depth
of water in the North Sea Basin approached 5,000m.
Therefore the history of the Basin has clearly been one of
progressive subsidence, leading to occupation by a
succession of shallow seas of different types, culminating
in the North Sea of the present-day. In the following
account the origin of the North Sea is traced from the
inception of the structural basin at the end of the
Carboniferous (270 m.y. BP) to the definition of more or
less the present form of the North Sea at the beginning of
the Tertiary (65 m.y. BP). (In the sequel: 'The History of
the North Sea' - Presidential Address for 1970, this story
will be brought up to the present-day.)

*School of Environmental Sciences, University of East
Anglia, NORWICH.

Fig. 1. Succession in the North Sea Basin off Norfolk
- (after Kent and Walmsley 1969)

BP 48/6-1   CONOCO 49/17-1

Sea bed

QUATERNARY 0   0

LOWER   Pleistocene   QUATERNARY

JURASSIC   Chalk   UPPER

500   500   CRETACEOUS

Lias

Rhaetic

Keuper

1000   1000

Muschelkalk

TRIASSIC   Upper   Bunter   TRIASSIC

1500   Middle   Bunter 1500

Lower   Bunter

2000   2000

UPPER   UPPER

Zechstein

PERMIAN   PERMIAN

2500   2500

LOWER

PERMIAN   Rotliegendes   LOWER

CARBONIFEROUS   Coal   Measures   PERMIAN

T.D. 2943 m.   CARBONIFEROUS

T.D. 2978 m.

	Shale, mudstone etc.		K K	Potash
	Sandstone		+.+	Halite
	Limestone		^ ^ ^	Anhydrite
	Ooliths			Dolomite

48/6-1

49/17-1

North Sea

Coal Measures times

At the time when the Coal Measures of the British Isles and N.W. Europe were accumulating, a vast expanse of deltaic and paralic (i.e. coastal) swamps existed right across the North Sea from the eastern United States (now separated from Europe by the Atlantic Ocean) to Poland. This region was bounded to the north by the Caledonian mountain chains whose remnants are found in Newfoundland, Scotland and Scandinavia, and to the south in part by open sea. Out of the swampy plains stood "islands" of Precambrian and lower Palaeozoic rocks, notable among which was the East Anglian-Brabant Massif, extending from the Midlands to Belgium. The rocks of this massif still exist only a hundred or so metres below the surface of parts of East Anglia. Nothing in this distribution of land and sea gives any indication of the ultimate site of the North Sea Basin, which was about to be delineated.

Towards the end of Coal Measures times mountain-building movements erected the Hercynian mountain chains running east-west through S.W. England and Brittany. A minor, though none-the-less substantial effect of these earth-movements was the raising of the anticlinal north-south axis of the Pennines - with complementary depressions on either side now forming the sites of the Irish and North Seas. Thus was the North Sea Basin initiated.

The Permo-Triassic (270 - 180 m.y. BP)

The raising of the Hercynian mountain chains cut off moisture-bearing winds from the area of the British Isles and adjacent North Sea, and this region, hemmed in between the Caledonian and Hercynian mountains became an arid area with internal drainage. Close parallels exist with the Basin and Range Province of the present-day western United States. However, it should not be forgotten that at this time there was also no Atlantic

Ocean, and the British Isles area was situated at about
30°N latitude, i.e. in equivalent latitudes to those at
present occupied by the Sahara desert.

During much of the Permian the North Sea Basin was
occupied by a hypersaline sea, with a restricted marine
fauna at times, and at others undergoing more extreme
evaporation to the point of precipitating potassium salts.

The lower part of the Permian is, however, represented
by the Rotliegendes Formation. In the south of the basin
this is composed of dune sands, which now form the
reservoir beds for North Sea gas, distilled from the
deeply buried Coal Measures underneath. To the north
these give way to siltstones with intercalated anhydrite,
and eventually to a basin containing rock salt or halite,
which terminates eastwards under Schleswig Holstein, and
extends westward as a belt across the North Sea towards
Yorkshire. From the lack of association of the halite
deposits with other evaporite minerals, Brunstrom and
Walmsley (1969, p.871) conclude that they were the product
of inland drainage.

The succeeding Zechstein Formation represents the
establishement of a hypersaline sea in the North Sea
Basin (see Fig. 2). It is represented at outcrop in
Northeastern England by the Magnesian Limestone, which is
in part a barrier reef at the edge of the Zechstein Sea.
Four cycles of evaporation are recognised in the Zechstein
deposits, the evaporite minerals from which have long
since been famous from their development at Stassfurt in
Germany. The main developments of rock salt are in the
Z_2 and Z_3 cycles (approximately 350 and 200m thick
respectively; see Fig. 1). These evaporite deposits
covered a wide area, the inflow of salt-bearing waters
coming from a marine area to the south.

Arid conditions continued in the following Triassic,
with extensive red bed deposition in the Midlands area of
the British Isles and the North Sea Basin (see Fig. 3).
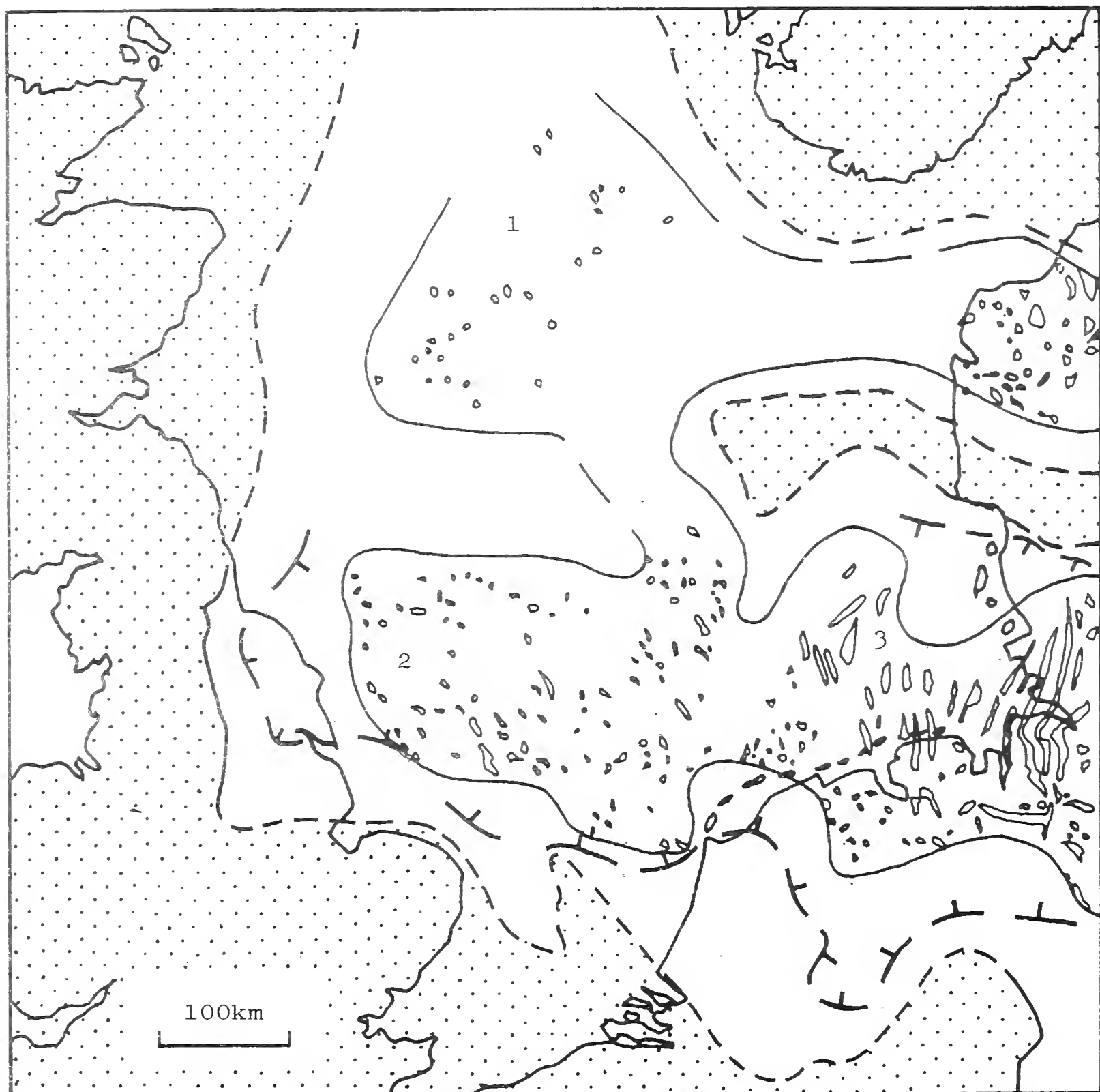
Fig. 2.   Permian deposits of the North Sea Basin (after
          Kent 1967A, and Brunstrom and Walmsley 1969)

Key: Limits of Zechstein
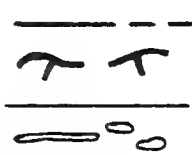   Limits of Zechstein salt
               Limits of area of salt plugs and masses
               Salt plugs and masses (including diapirs)
               1. Norwegian Salt basin 2. English Salt basin
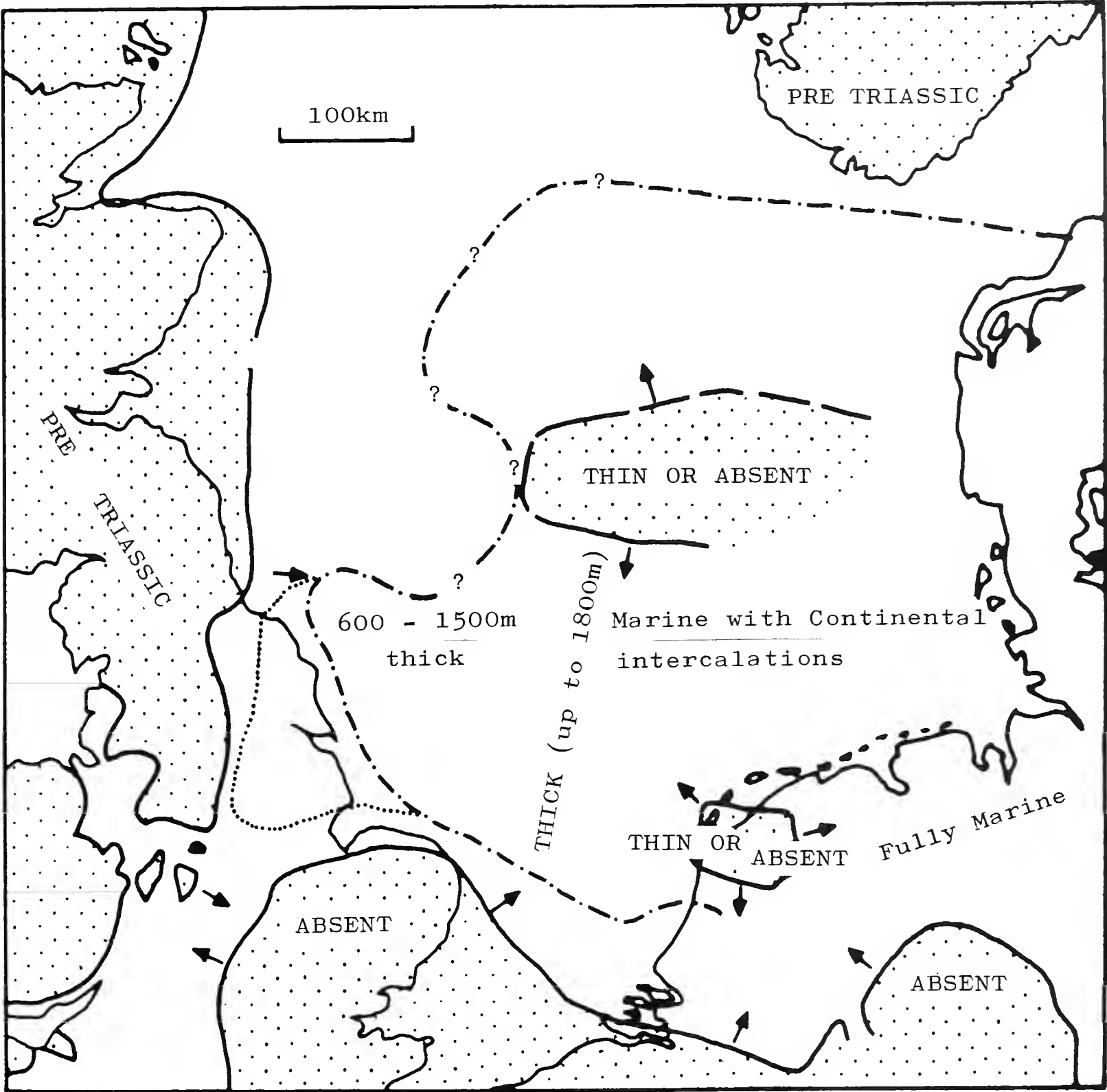   3. German Salt basin.

Fig. 3.   Triassic deposits of the North Sea Basin
           (after Kent 1967A)

Key: Limits of Triassic deposits   ——————————
           Limits of Muschelkalk Sea   —·—·—·—·—
              (minor marine tongue)   ·······················

Differential movements and block-faulting, possibly
associated with the earliest phases of opening of the
Atlantic Ocean, were rather characteristic, and the
accumulation of considerable thicknesses of sediment
led to incipient halokinesis or salt tectonics affecting
the underlying Zechstein salt beds (see Fig. 4).
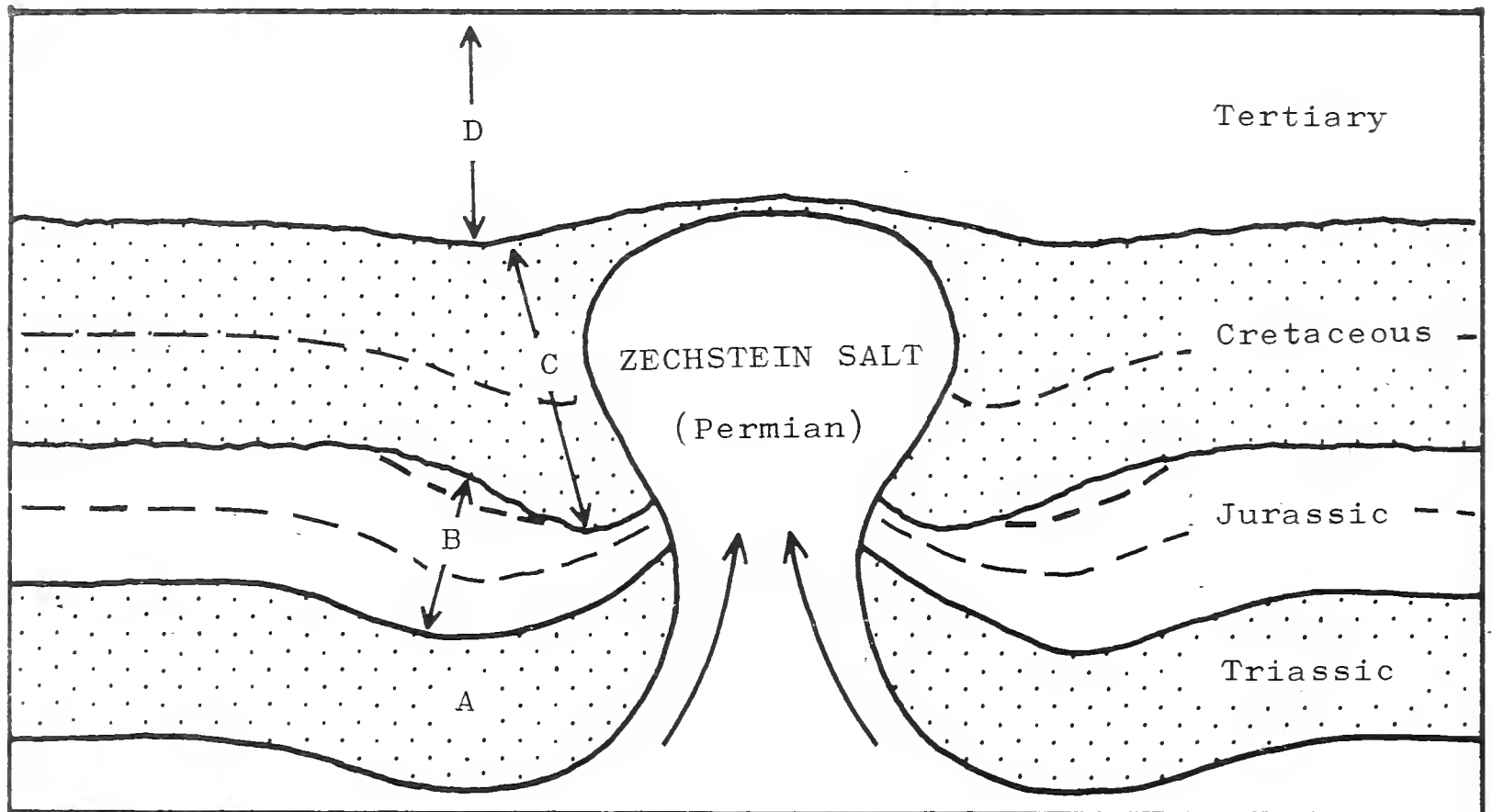
Fig. 4.   Idealized section through a North Sea Basin salt
          plug and adjacent strata   (after Brunstrom and
          Walmsley 1969)

          A. Pre-movement stage (Triassic)
          B. Pillow stage; primary peripheral sink
             develops (uppermost Triassic and Jurassic)
          C. Diapir stage; secondary peripheral sink
             develops (Lower and Upper Cretaceous)
          D. Post diapiric stage; third-order peripheral sink
             (Tertiary)

The Bunter division, which in the Midlands consists of pebble beds and dune sands, passes laterally under the North Sea onto marley beds containing fine sandstones and thin developments of rock salt and anhydrite. The middle division of the German sequence - the Muschelkalk, which represents the development of a hypersaline sea with an impoverished fauna, is found extensively under the North Sea and extends close to the present coast of the British Isles. There was a small ephemeral extension onto the arid plains of the east Midlands. The main development of the Muschelkalk consists of alternations of mudstones, dolomites, rock salt and gypsum. The Keuper division, succeeded by the lagoonal marine deposits of the Rhaetic, which heralded the return of the normal salinity Jurassic seas, is widespread. However, the thickness of sediment resting on the Zechstein salt was already approaching or even exceeding 1000m before the end of the Triassic, and both Keuper, and particularly Rhaetic, may be absent through erosion from above salt culminations (pillows or domes).

Jurassic and Lower Cretaceous (180 - 100 m.y. BP)

The movement of salt which commenced in late Triassic times continued actively in the Jurassic and Lower Cretaceous, and abnormal thickening of deposits occurred between the active salt plugs (see Fig. 4).

Generally speaking the Lower Jurassic, or Liassic, sequence is well-developed (Fig. 1), but even this has often been removed by pre-Upper Cretaceous erosion. The Middle and Upper Jurassic actually thins eastwards towards the North Sea from its fullest development in the Midlands, as does the Speeton Clay of the Lower Cretaceous succession, and Jurassic and Lower Cretaceous sediments are thin or absent over considerable tracts of the North Sea Basin (Fig. 5). Much of this absence is probably the result of pre-Upper Cretaceous erosion, and both halokinetic and tectonic movements are clearly factors contributing to it.

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Thus it is clear that during the Jurassic and Lower Cretaceous the North Sea Basin did not form a major site of marine sedimentation, although continuity of marine waters across the area is implied - for instance by the similar faunas of the Yorkshire and Lincolnshire and the Netherlands Lower Cretaceous.
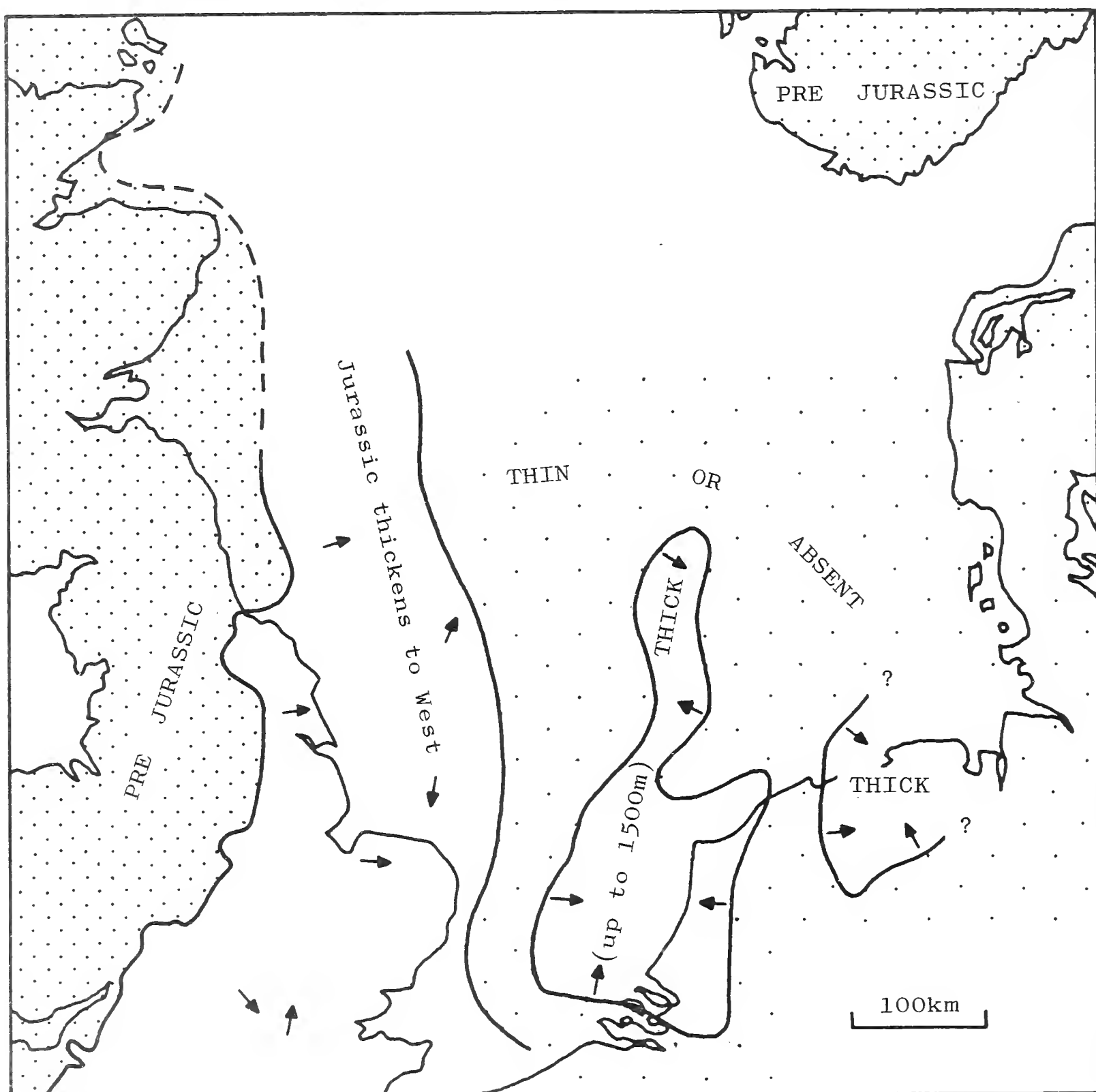

Fig. 5.   Jurassic and Lower Cretaceous deposits of the North Sea Basin (after Kent 1967A)

Upper Cretaceous (100 - 65 m.y. BP)

Following the extensive halokinetic and other
tectonic events of the Jurassic and Lower Cretaceous,
with their accompanying erosion and localised
deposition, the Upper Cretaceous was a period of
extensive transgression. The sea spread broadly over
both the North Sea Basin and surrounding areas (see
Fig. 6). Apart from an initial period during the Albian,
when erosion of exposed Triassic rocks in the North Sea
Basin is thought to have contributed to the red colour
of the Red Rock, the deposits were typically the same
pure white chalk which characterises the Chalk formation
on land. The presence of a basal Red Rock member,
similar to that developed in Norfolk, Lincolnshire and
Yorkshire, is typical, and extends eastwards as far as
the Netherlands.

Thicknesses of up to 1,500m of Chalk are found in
places, although it is thin or absent through erosion
under the northern Netherlands, in a belt which extends
half-way across the North Sea towards the Norfolk coast.
It is also absent along an anticlinal zone extending
parallel to the coast of Yorkshire and North Lincolnshire,
within which Jurassic rocks outcrop on the sea floor.
Salt movement continued during Upper Cretaceous times
and locally Upper Cretaceous is absent through salt
dome piercement of the Chalk formation.

Generally speaking, during this period the North
Sea Basin formed only part of a much more extensive
epicontinental sea, which flooded large areas of the
British Isles and N.W. Europe. The Basin itself is only
distinguished by the accumulation, in parts at least, of
rather greater thicknesses of sediment than characterise
the surrounding areas.

The North Sea

At the end of Upper Cretaceous times there was a
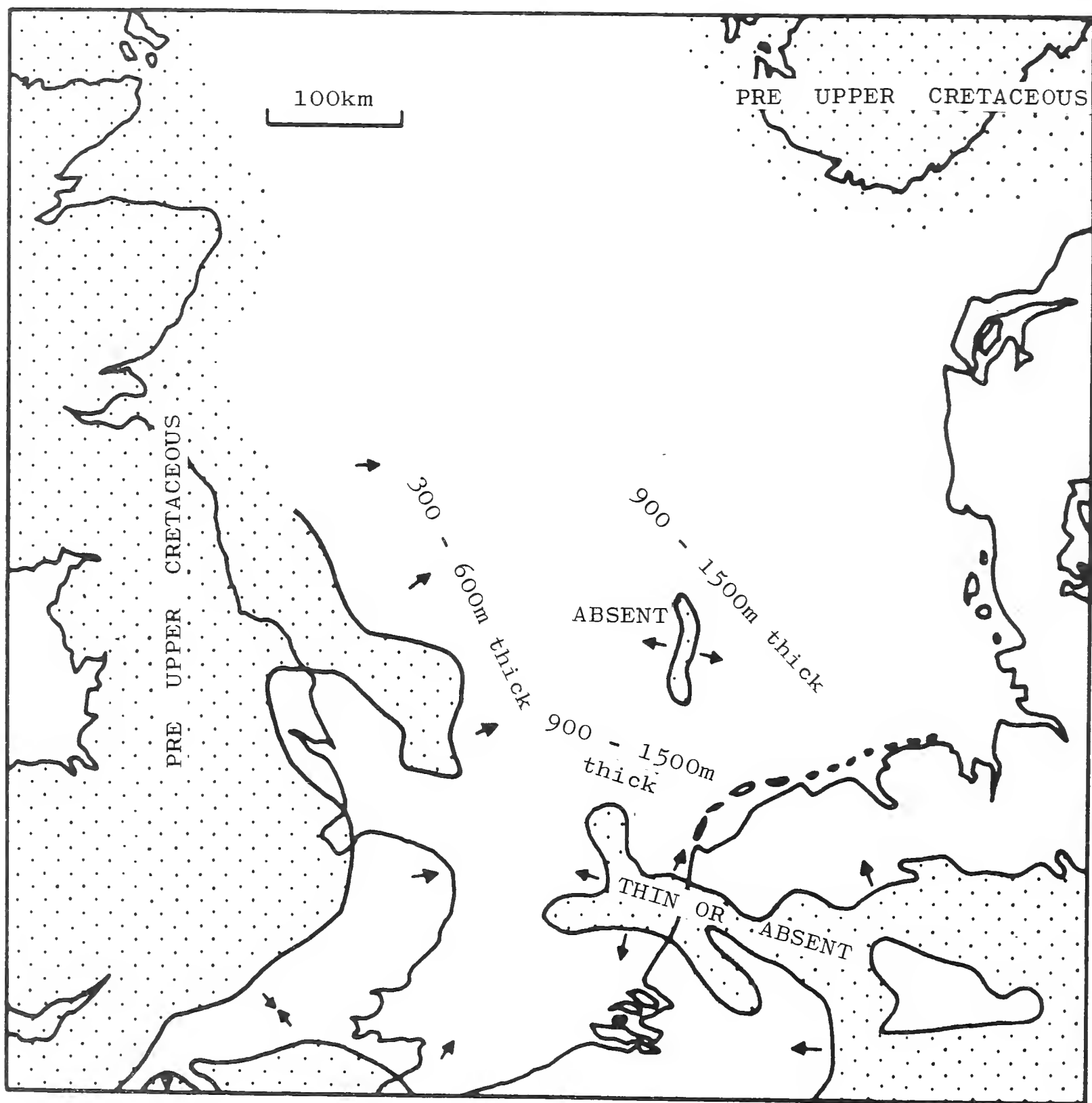widespread regression of the sea, associated, or at least

Fig. 6.   Upper Cretaceous deposits of the North Sea
          Basin (after Kent 1967A)

concomitant with tectonic movements, that may themselves
be related to the opening of the Iceland branch of the
North Atlantic Ocean. At this time, or shortly following
it, volcanic activity is noted at the eastern edges of the
North Sea Basin (although nothing like as extensive as the
contemporaneous volcanism of the Scottish Islands), and
the present outlines of the Basin were largely defined.
The Basin thus defined was occupied continuously by
marine waters throughout the Tertiary until the present-
day, and accumulated considerable thicknesses of
sediments (see Fig. 7). From this time onwards the marine
waters occupying the Basin can appropriately be referred
to as the North Sea, and their history will form the
subject of the sequel to this account, in the next issue
of the Bulletin.

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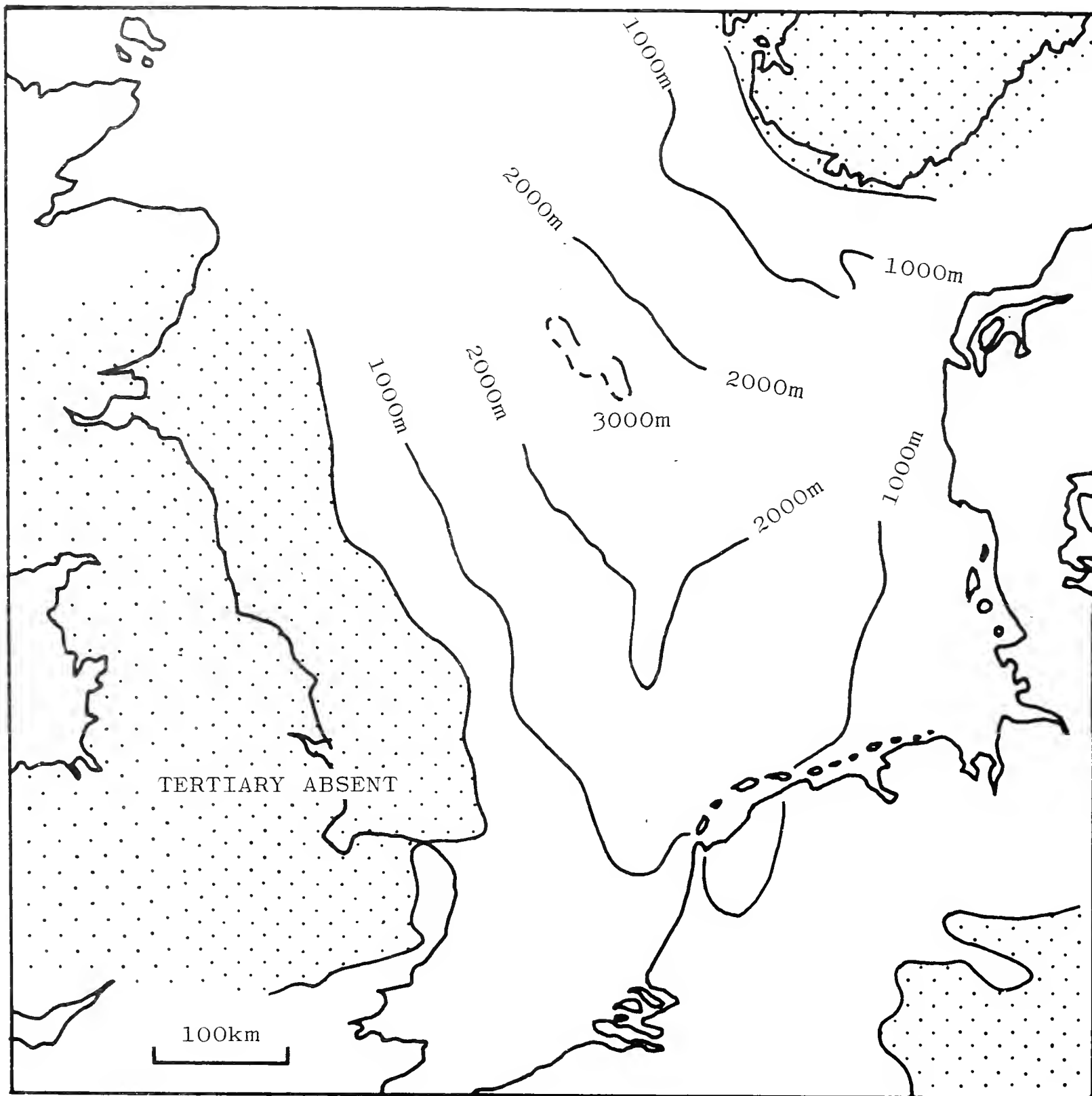   Hull publ.

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Fig. 7.   Thickness of Tertiary deposits in the North
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ASPECTS OF GEOLOGY IN EDUCATION

H. EVANS*

All subjects within the curriculum have a limited vocational factor relative to the supply and demand of society. Geologists have been aware of such a situation for many years, and it is one which has now affected other natural sciences. It is a personal opinion that this has resulted in conservative elements within geology neither actively encouraging nor discouraging the teaching of the subject in schools. This is, in effect, a restrictive practice based on vocational considerations. The result has been to limit the degree of educational research into geology as a discipline of value within the school curriculum. From such a weak position it is difficult to justify its existence in competition with traditional subjects, while further limitations are imposed by economies of scale within, for instance, a grammar school. These are probably too small to consider real expansion of both curriculum and specialist staff. Therefore the excess of graduate geologists, who wish to teach, is often unable to find desirable employment in schools.

A. E. Trueman (1947) states, "Teachers must not think too exclusively of those who are to be professional geologists". In context this statement applied to school teachers, but this in no way invalidates its application to those in higher education. The expansion of the universities during the 1955 - 65 period enabled such attitudes to be inculcated, particularly with non-vocational Foundation and subsidiary courses. The newer universities were able to break with tradition and pave the way for wider curricula based on liberal thinking. Similarly, the number of courses now being offered by

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Extra Mural Studies and the Workers' Educational
Association is some indication of the growing interest
in recreational geology and allied subjects. The
Foundation Courses of the Open University are a further
indication of this trend.

Certainly, during the post-1945 period, geology in
schools was predominantly restricted to industrial areas
where its vocational considerations were fully realised.
Since then there has been a steady growth in the number of
General Certificate Examination entries and inroads have
been made in the C.S.E. Mode 3 examination. To complement
this, several colleges of Education now include geology
for the Bachelor of Education degree. If growth is to
continue in schools then this is most likely to be met by
the larger units - comprehensives, large grammar and
technical schools, where economies of scale are greater.
It is only within such a unit that the recommendations of
the Dainton Report (1968), with its emphasis on a broad
span of sixth-form studies in science and technology, can
be fully realised.

The potential for geology in a technical college is
significant because of its utilitarian value in terms of
arts, science and technology. Where courses are
academically oriented, that is to O and A levels,
it provides opportunities for science-based students with
vocational aspirations in geology, or for arts students
who intend reading geology at a subsidiary level to
geography at university. Further opportunities are now
provided by the innovation of university earth science
courses with their wide appeal of option courses. In this
respect it is interesting to note that K. Clayton (1970)
considers earth sciences as offering a conversion towards
science for the sixth-form arts student, an opinion which
appears to concur with Dainton's suggested postponement
of irreversible decisions for or against science as late
as possible. In my experience there has been little to

choose between science or arts based students in
geology at A level, though one naturally accepts the
relevance of a science based course for specialised work.
One must not underestimate the growing importance of
Environmental Studies in the Colleges of Education, since
a variety of subject combinations, including geology,
can provide a sound base for teaching, particularly where
team teaching is incorporated within a school.

Courses within my own college have been organised
for teachers in which both theory and subject techniques
have been an integral part of the course. This has
directly influenced the introduction of geology in a local
school. As a service department, it has been of
particular use with building courses, by providing
information and materials on basic rock-types. In this
connection a course has been run for local building
firms.

Geology Teaching

Most of the students elect for geology A level with
little or no previous experience of the subject.
Therefore it is essential that material must be carefully
selected for its wide appeal, since future student
attitudes will possibly depend on the introduction to
the subject. The following points of observation are
critical in developing confidence, and a class rapport
between teacher and taught. I might add that they can
be equally applied to any other subject.

(i) The majority will have a lack of confidence in
commencing a new subject.

(ii) They will tend to measure progress against a text-
book standard, and regard their own intellect with
a sense of inferiority.

(iii) Teaching appears to promote a state of perfection
in which errors must be apprehended, often to the
detriment of student or pupil confidence. This
form of punishment within a learning situation

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can stifle all subsequent discussion; even of
the simplest problems.

It is possible to organise the subject matter in
many ways, which could be discussed at length. The most
usual practice is to teach the individual branches of the
subject concurrently, a method which tends to follow
closely the outline of an examination curriculum. The
advantages of this system can be fully exploited if there
is a continuous integration of material; otherwise it is
some time before a student realises the implications of
geology.

As an alternative I suggest three group studies or
natural divisions in which maximum continuity and
integration is feasible, and provides a large measure of
success and satisfaction for the student.

The first grouping,(Fig. 1), is a natural division
based on igneous petrology, but with an integration of
earth ·structure, mineralogy and ore deposits. The

Earth Structure

Seismology   Igneous   ⟶ Mineralogy
                              Petrology

Vulcanicity   Ore Deposits ⟶

        Intrusions   Weathering of
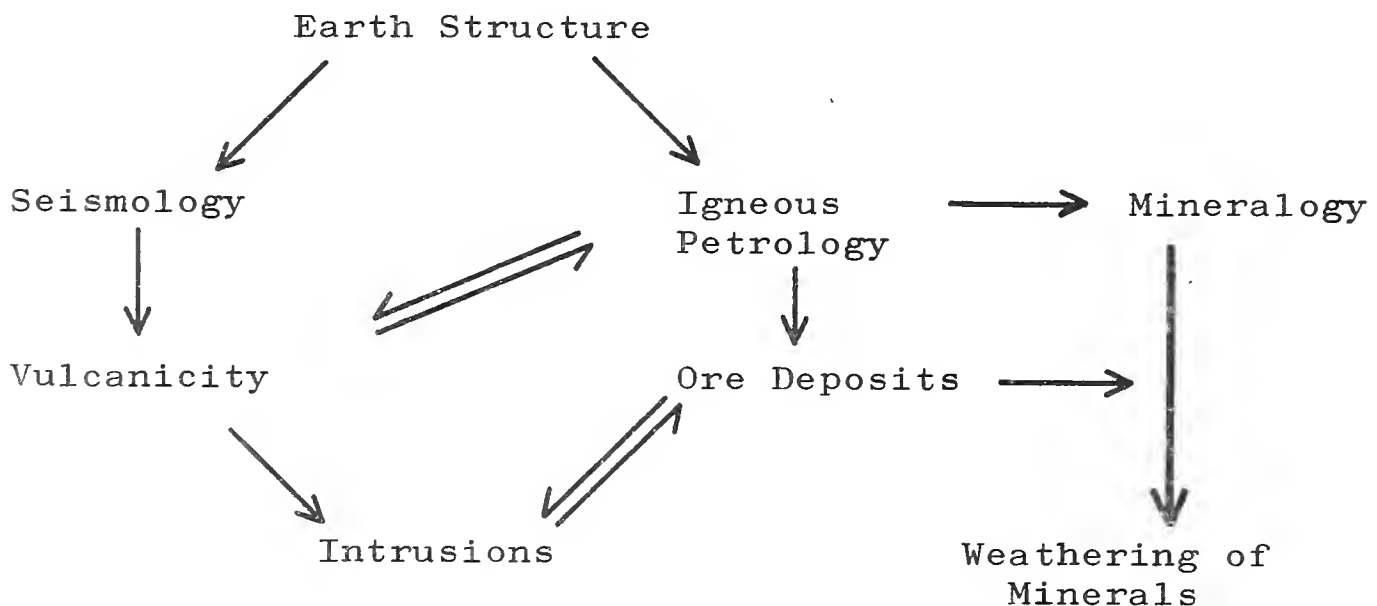   Minerals

Fig. 1. Group Study showing the integration of
          allied topics based on igneous petrology.

introduction of a stimulating topic like vulcanicity in
the early part of the course has advantages. The students
already have some previous knowledge which does contribute
to a higher degree of oral response, and more effective
teaching as a result. This also has the effect of
instilling confidence. It is essential at this stage to
introduce rock and mineral specimens, even with the first
lessons on simple magmatic differentiation and textural
considerations. One cannot expect granites to be
identified without some knowledge of the mineral
constituents in both theory and hand-specimen. The
intention is to avoid classifications and mineral content
being learned on a rote method, so that application,
rather than knowledge for its own sake is encouraged.
The mineralogy follows a sequence in which the rock
forming minerals are followed by those of economic geology.
The introduction of weathering at this point is relative
to the mineralogy, and introduces the second groupihg.

      This grouping, (Fig. 2), has a predominantly
sedimentary theme initiated from a study of erosive
forces, and correlated with both palaeontology and
stratigraphy. The environmental concept can be a unit
in which a euxinic, deltaic or desert environment, for
example, can be directly selected from a geological
period, but it is moderately difficult to elucidate
stratigraphical principles from such units. Therefore
examples are chosen from Lower Palaeozoic sedimentation,
which correlate rock-types and structures with a study
of graptolites and trilobites. Within this context the
discussion of time, zones and facies change form a natural
linkage factor. Further studies can include limestone
diagenesis - Wenlock or Lower Carboniferous bioherms -
corals, crinoids; or sandstones and structures -
Carboniferous deltas - rhythmic sedimentation -
lamellibranchs. The brachiopods, lamellibranchs and
gastropods are difficult to correlate because of their

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Erosion

Principles of
Stratigraphy

Environmental concept
of Sedimentation

Palaeontology

Rock-type and
diagenesis

Concepts of
time. Zonation

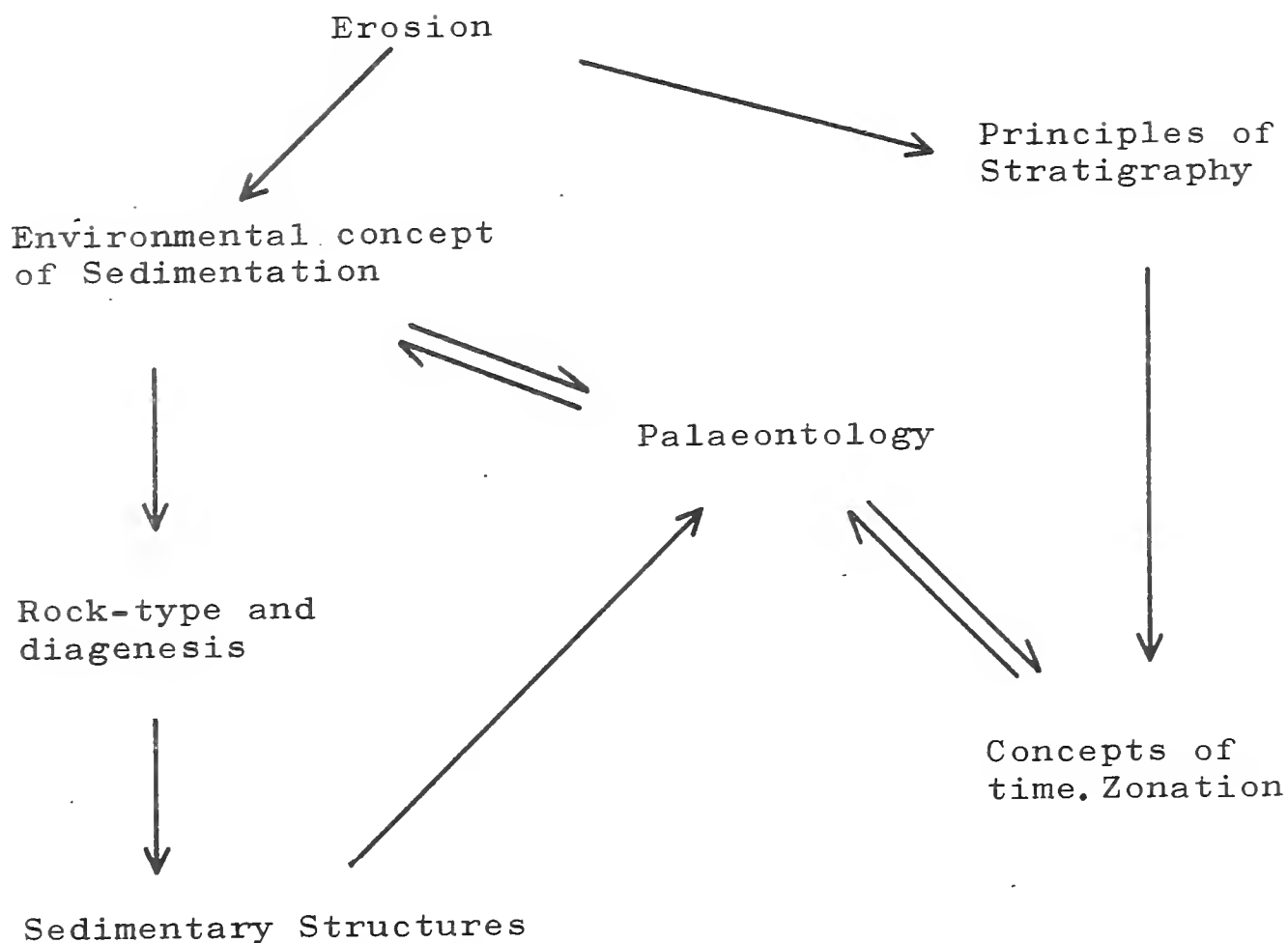Sedimentary Structures

Fig. 2.   Group Study illustrating the relationship
           between three major branches of geology
           and their organisation for teaching.

adaptation to a broad range of environmental conditions
throughout geological time, and there is a danger of
fragmented teaching. In this case they are regarded as
units and this does have the effect of extending the
course outside its grouping.

A third grouping consists of metamorphism linked
with geosynclinal concepts, mountain building and
continental drift, a course which, in view of the time
factor, runs concurrently with stratigraphy. The
foundation for the latter has already been laid and
enables the student to view the subject with some measure

of proportion. This is not always achieved, but can avoid lists of beds rather than an intelligent and interesting interpretation of events.

The teaching of structural geology and map interpretation is coordinated with the main groups of work. Initially, the maps are a source of reference, but they broaden into the wider aspects with the introduction of stratigraphical principles in the second group of study (Fig. 2). Of course one is actually teaching these principles from the first field trip. Field work follows a similar pattern so that a course on the Lower Palaeozoics of North Wales or Shropshire is conducted at the end of the first year, and contrasted with the Mesozoic of the East Riding or Dorset during the second year. Local day excursions also form a significant part of the course.

In terms of time, based on six-hourly periods per week, the first group study is likely to take 18 to 20 weeks, the second group study some 13 to 15 weeks but with an extension of time for palaeontological groups. The stratigraphy and the third group study run parallel, the former taking a substantial part of a second year course.

It is of course possible to rearrange these groupings, and commence with the principles of geology. I prefer this method for reasons stated in the introduction to this section, and consider that the group system has the following advantages.

(a) There are no barriers across the timetable; one can organise work without fear of cutting across some other branch of geology.

(b) Students can concentrate on a main theme rather than a disjointed approach, this provides continuity.

(c) The integration of work provides for a much more fluent approach to both written and oral work, and there is continuous recapitulation.

(d)   The use of specific examples becomes multipurpose
       rather than a limiting factor.

Resources

       The choice of A-level text-books is limited and those
available leave a lot to be desired in terms of content,
and particularly from the point of view of material
written in an interesting way. There is little attempt
to demonstrate the inter-relationships between various
branches of the subject, which can result in a form of
'pigeon-hole' thinking. Students require little
encouragement in this respect. There are very few books
written on stratigraphy, while crystallography is often
regarded as a glossary of axes and crystal forms. In view
of this situation, most material has to be carefully
selected and supplemented by reference to duplicated notes,
scientific journals and selected reading. Fortunately I
have access to a first class library at my own college.
Visual aids normally consist of slides, overhead
projectors, photographs and to a lesser extent films.

       Perhaps the most useful resource is the collection of
rocks and fossils which provide a focal point for the
majority of lessons. The mass of material carried can
reach alarming proportions, particularly with some common
igneous rocks and limestones. An attempt is made to
provide as many class collections as possible so that
classroom organisation is reduced to a minimum, while at
the same time the interest of the individual can be
maintained. A further feature is the portability of such
collections in using a variety of rooms. The cost of
supplying and maintaining collections is relatively
small since much material is collected on excursions, and
some is donated by interested staff and friends of the
college. Though thin-section studies are no longer a
part of the London syllabus, microscopes are used for
examining textures of igneous and metamorphic rocks.

       The regional position of King's Lynn is such that

it is not reasonably endowed with a variety of suitable outcrops. Full use is made of local geology, but day excursions have to be made to the Jurassic of the Stamford area or the Pre-Cambrian of Charnwood Forest. Reference has already been made to other excursions. An important aspect of this work is to encourage an appreciation of the countryside in its widest context, and to have consideration for an outcrop which may have intrinsic value to someone else.

Any future development of geology, either as a single discipline, or under the guise of environmental studies, will only do so through an expansion of the curriculum. This will initially depend on increased expenditure on education, and possibly where schools are re-grouped into larger units. Compared with traditional subjects there is a general lack of comprehension of both its content and value; a state which can be overcome through educational research.

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THE ZONES OF THE GIPPING VALLEY CHALK, SUFFOLK

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Jukes-Browne (1903) referred the Gipping Valley Chalk to the Zone of <u>Actinocamax quadratus</u>, and Boswell (1912) recorded the overlying <u>Belemnitella mucronata</u> zone from Bramford. The <u>quadratus</u> zone of the Gipping Valley was called the zone of granulated <u>Actinocamax</u> by Brydone (1932), as the old zone of <u>A. quadratus</u> in the south of England had by then been divided into a lower zone of <u>Offaster pilula</u> and an upper zone of <u>Actinocamax quadratus</u> (restricted). Gaster (1941) referred the chalk below the <u>mucronata</u> zone in the Gipping Valley to the zone of <u>O.pilula</u>, concluding that the <u>A. quadratus</u> zone (restricted) was missing.

In the nineteen-fifties, plates of the zonal crinoid <u>Marsupites</u> were found by C. Allen and R. Markham in the lowest chalk exposed in 'Masons' pit, Great Blakenham (TM 112499).

In the mid nineteen-sixties, chalk with <u>Gonioteuthis (=Actinocamax) quadrata</u> was found above the chalk with <u>Belemnitella</u> at Church Lane, Claydon (TM 136498). Peake and Hancock (1961) suggest that <u>Belemnitella</u> from their <u>Gonioteuthis</u> zone (=Brydone's zone of granulated <u>Actinocamax</u>) in Norfolk may be <u>B. praecursor</u>; several specimens of <u>Belemnitella</u> (of the type formerly thought to be <u>B. mucronata</u>) from Claydon and Bramford (TM 129482) were kindly identified for the writer by M. R. Leeder as <u>B. praecursor</u>. It now appears that the zone of <u>Belemnitella mucronata</u> does not occur in the Gipping Valley, which solves several problems ——

<u>Gonioteuthis (=Actinocamax) granulata</u> does not occur zonally higher (i.e. immediately under <u>mucronata</u> chalk) in Suffolk than elsewhere (Boswell 1927), and there is no

* Ipswich Museum, High Street, IPSWICH.

need for an unconformity between <u>mucronata</u> and <u>pilula</u> zones (Gaster 1941). The thickness of the <u>Gonioteuthis</u> zone (s.l.) is probably similar to other parts of the country.

The Gipping Valley Chalk shows <u>Gonioteuthis</u> zone on <u>Marsupites</u> zone; the <u>Gonioteuthis</u> zone may be subdivided into an upper, <u>quadrata</u> zone and a lower, <u>pilula</u> zone. <u>Gonioteuthis</u> of the <u>granulata</u> type is characteristic of the <u>pilula</u> division.

Until more detailed studies are made, the Gipping Valley Chalk may for practical work be divided as follows -

5 - division of <u>Gonioteuthis quadrata</u>

4 -   "   "   <u>Belemnitella</u>

3 -   "   "   <u>Gonioteuthis</u> and <u>Echinocorys</u>

2 -   "   "   <u>Gonioteuthis</u> (<u>Inoceramus</u> and <u>Ostrea</u> also common)

1 -   "   "   <u>Gonioteuthis</u> and <u>Marsupites</u>

The alveoli of <u>Gonioteuthis</u> in division 5 are generally deep and quadrate; in divisions 1, 2 and 3 the anterior ends of the guards are usually imperfect, and the few alveoli seen are not quadrate nor quite so deep.

Bands of flint nodules are common in divisions 4 and 5. <u>Echinocorys</u> is common in divisions 3, 4 and 5, but less so below. Little work has so far been done on thicknesses, but division 2 is the thickest.

The echinoid <u>Micraster</u> may here be recorded from Bramford (Brydone collection, in Ipswich Museum) and Claydon (found by R. Forsdike).

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A FOREST BED HORSE JAW FROM PASTON, NORFOLK

R. A. D. MARKHAM*

In the collection of Dr. W. H. Miller of Mundesley
is a fine mandible of horse, found on the beach at
Paston; the state of preservation and adhering matrix
leave little doubt as to derivation from nearby Forest
Bed deposit.

Most of the left side and portion of the right side
are preserved. On the left side the ascending ramus is
missing; all six cheek-teeth are present, also the canine,
but of the incisors only I_1 is perfect, 2 and 3 being
broken off below jaw level. On the right side, all the
incisors are broken below jaw level; the canine and one
cheek tooth (second premolar) are present, the jaw being
broken off behind this.

Left side:

Diastema length, I_3 - P_2 c. 113 mm.
(measured between base of teeth;
difficult as I_3 broken)

Length of cheek-tooth row, P_2 - M_3 207 mm.
(grinding surface) (measured from
end of parastylid of P_2 to end of
hypoconulid of M_3)

Length of premolar series (grinding   108 mm.
surface) (measured from end of
parastylid of P_2 to outer edge of
hypoconulid of P_4)

Height of ramus at P_4 M_1 106 mm.

Height of ramus at centre of M_3 c. 132 mm.

Height of ramus at rear of M_3 c. 147 mm.

* Ipswich Museum, High Street, IPSWICH.

R. A. D. Markham

Left side

Top

15

10

5 CM.

0

LM3̄

LpM4̄
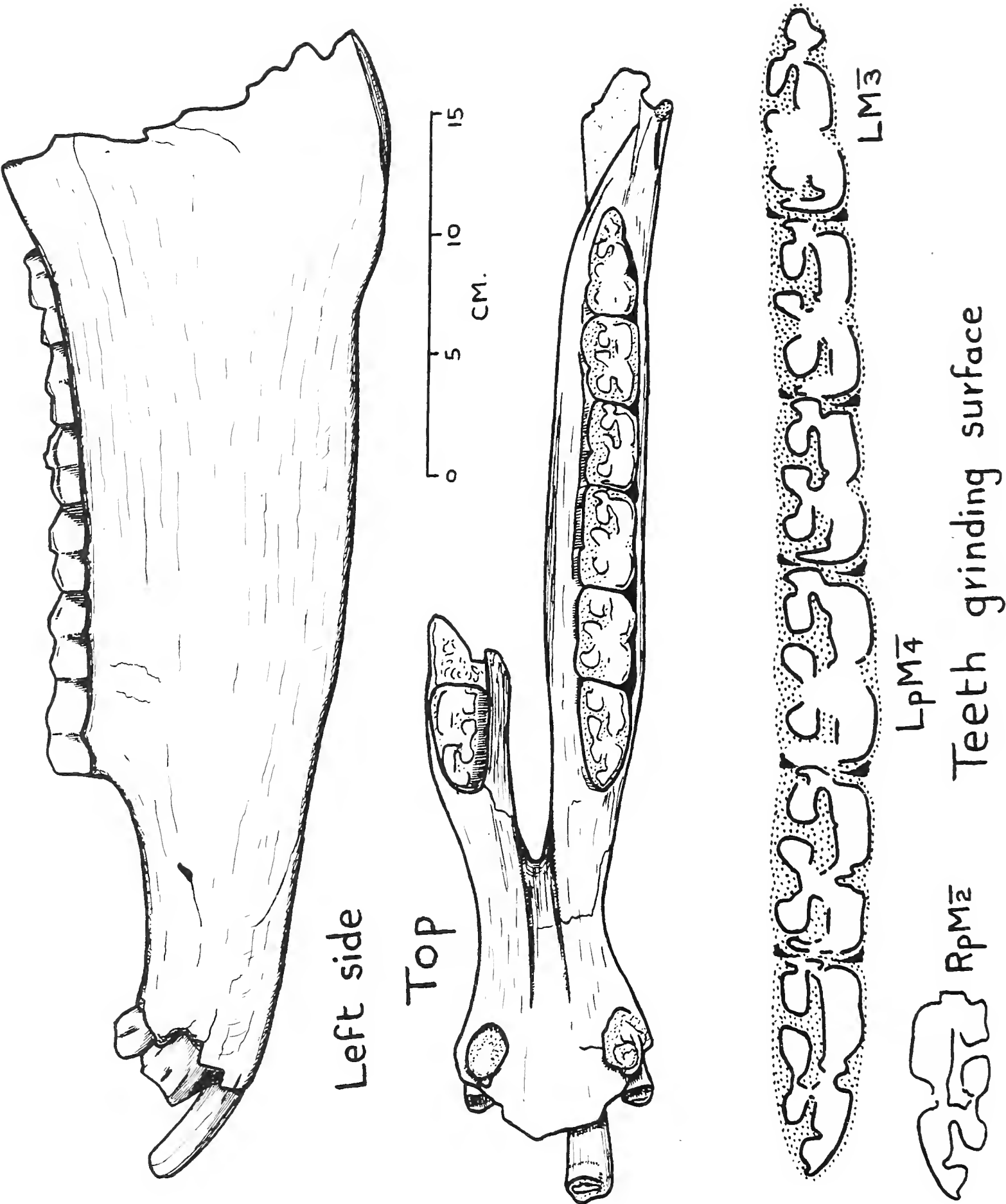
RpM2̄

Teeth grinding surface

Fig. 1. Horse jaw from Forest Bed, Paston

Right side:

Diastema length, I_3 - P_2 c. 115 mm.

(measured between base of teeth,

at edge of socket; difficult,

as I_3 broken).

Adhering matrix obscures the metastylid -
mesostylid valley in LM_3, LM_2 and LpM_4, but in the rest
of the cheek teeth it is close to the "U" shape of the
caballine horses and is unlike the "V" of the so-called
zebrine group. The complete incisor shows the cup or
'mark' on the wearing surface.

I wish to thank Dr. Miller for permission to
examine and note this specimen.

RAILWAYS AND GEOLOGY - A WALK FROM NORTH WALSHAM
TO PASTON AND KNAPTON
(Field Meeting, June 3, 1971)
R. S. JOBY

The branch line from North Walsham to Mundesley
traverses superficial glacial deposits of varying
types and also crosses the valley of the River Ant.
This provided an opportunity to examine exposures
in cuttings, which revealed rapid transitions from
sand to clays, and back again. Vegetation variations
on the differing deposits were also noted.

The remains of the ballast on the roadbed appear
to be Kelling Heath gravels, quarried by the M. & G. N.
Railway in its own pit. This is mixed with furnace
slag. More recent non-local material noted was a
finer gravel used in connection with the use of the
roadbed as a gas pipeline route, and this appeared
to be markfieldite.

The alluvium of the Ant valley was easily picked
out by the change in vegetation, which coincided
almost exactly with the boundary on the 1" Geological
map. Other geological boundaries shown on the same
map were not so readily discernible, and there
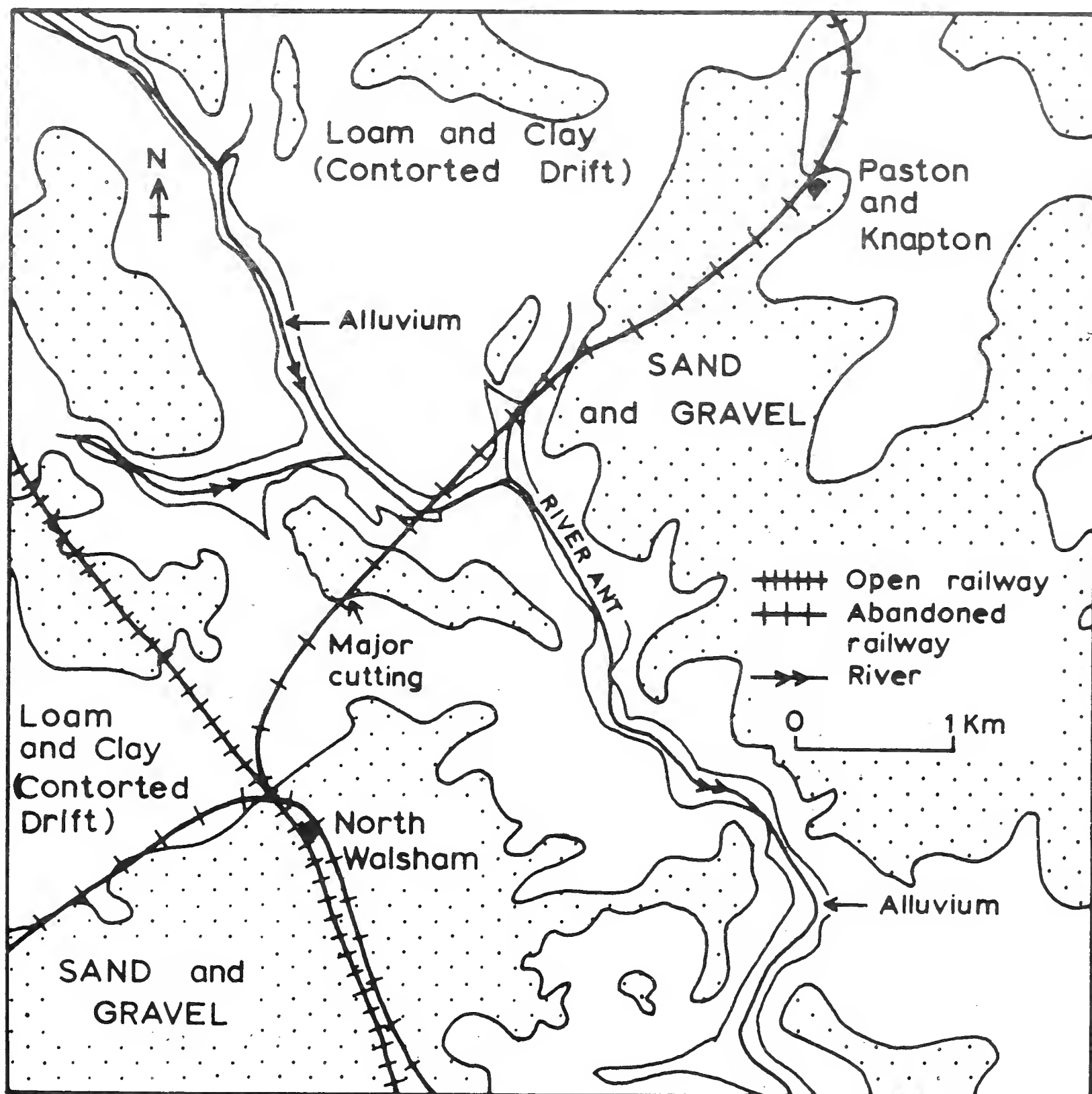appeared to be a zone of change in the deposits rather
than a distinct line.

Fig. 1. Superficial Geology of North Walsham area

REPORT ON FIELD MEETINGS TO WANGFORD, AND
EAST SUFFOLK

P. G. CAMBRIDGE *

Two field meetings on July 8th and August 1st 1971
included visits to representative sections of most of the
East Anglian Crags, with the exception of the
Waltonian and Weybournian stages which were not seen.

Hill Farm, Wangford (TM 462777)

In 1969 a section was re-excavated in an old pit
showing shelly Norwich Crag of littoral type, passing up
into bedded gravels. Recent workings in the gravel pit
to the northern side of the road have reached the base
of these gravels and penetrated shelly sands.
Unfortunately, owing to the method of working the
gravels, the junction between the two types of deposit
could not be clearly seen, but there seemed no reason to
suspect that it differs from the top of the section in
the old pit. Five members attended the meeting and
representative collections of the abundant molluscan
fossils were made. The abundance of Donax vittatus
(Da Costa) and the large size and excellent preservation
of the examples of Littorina littorea L. and Nucella
lapillus (L) attracted attention. Several fragments of
mammalian bones, possibly elephant, were found, while
the author found a single valve of the freshwater bivalve
Corbicula fluminalis (Müller) in a sample. Finally an
interesting bed of Fragaria vesca was discovered on the
the side of the valley and the meeting was extended to
enable members to collect - and eat - these delicious
wild strawberries.

East Suffolk

Twelve members and friends assembled at Orford
Castle and climbed the keep. Visibility was very good and
parts of the coast from Walton-on-the-Naze to Aldeburgh
were seen. The general distribution of the Crag beds,

* 258 Bluebell Road, NORWICH.

the drowned valleys and the structure of Orford Ness were discussed.

The first exposure was at Crag Farm, Sudbourne (TM 429523) where a good section was seen in the bullockyard. It was a common practice to cut bullock-yards in the Crag and to use the material excavated for farm roads, rough walling or spreading on the land. The Coralline Crag Rock Bed is partially decalcified so that aragonite fossils were seen only as moulds in the rock, (Laevicardium, Glycymeris, etc) while calcitic fossils remain (Pycnodonte, Anomia, Lima, polyzoans, crustacea). At this pit the current bedding was well seen and, along what appeared to be joint planes, some traces of Red Crag were noted, showing that the Red Crag formerly enveloped the Coralline Crag deposits.

After refreshments at the Oyster Inn, Butley, the Church Pit at Chillesford (TM 383523) and the Neutral Farm Pit, Butley (TM 371511) were visited. The composite section in the two pits shows Butleyan Red Crag overlain by the Scrobicularia Crag and the Chillesford Crag. The Red Crag of this stage contains many large bivalves as well as small well-preserved molluscs (Calyptraea, Ringiculella, Odostomia, Mangelia, Nassarius, Hiatella). An example of Spirotropis modiola (Jan), was found in the Neutral Farm Pit, almost certainly derived from the Pliocene and demonstrating the reworking that continued throughout the Red Crag.

Examples of the typical Scrobicularia plana (Da Costa), an estuarine form, were collected in the Church Pit and it could be seen how conditions were altering. Coarse shelly shands, strongly current-bedded, which are typical of the Red Crag, give way to silty layers of increasing thickness in which examples of Spisula and Macoma were seen with the valves still joined. In the Chillesford Crag in the upper part of the Church Pit members saw Mya truncata L. in the position of growth, emphasising

the undisturbed aspect of the beds.

The last pit visited was a sand and gravel working on Waldringfield Heath (TM 263448) in glacial outwash. There is a distinct change in lithology between the pale waterlaid sands of the outwash, and the darker marine sands of the Crag. Although decalcified, these upper layers show signs of biogenic activity in the form of numerous burrows, partially solidified by iron compounds (?Balanaglossus). Similar burrows are seen in the Scrobicularia Crag, at Chillesford, and elsewhere. A large pumping trench in the bottom of the pit penetrates the shelly Crag of the Newbournian stage. Acropagia, Mya, Arctica, Neptunes, Nucella and other molluscs were collected. Near the bottom of this trench were numerous phosphatic nodules, worn fish teeth and fragments of Coralline Crag and London Clay, which may have come from the basal nodule bed of the Red Crag.

Our thanks are due to the owners and occupiers of the land who freely gave permission to examine the various sections and thus made the meetings possible.

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The Geological Society of Norfolk exists to promote the study and knowledge of geology, particularly in East Anglia, and holds monthly meetings throughout the year.
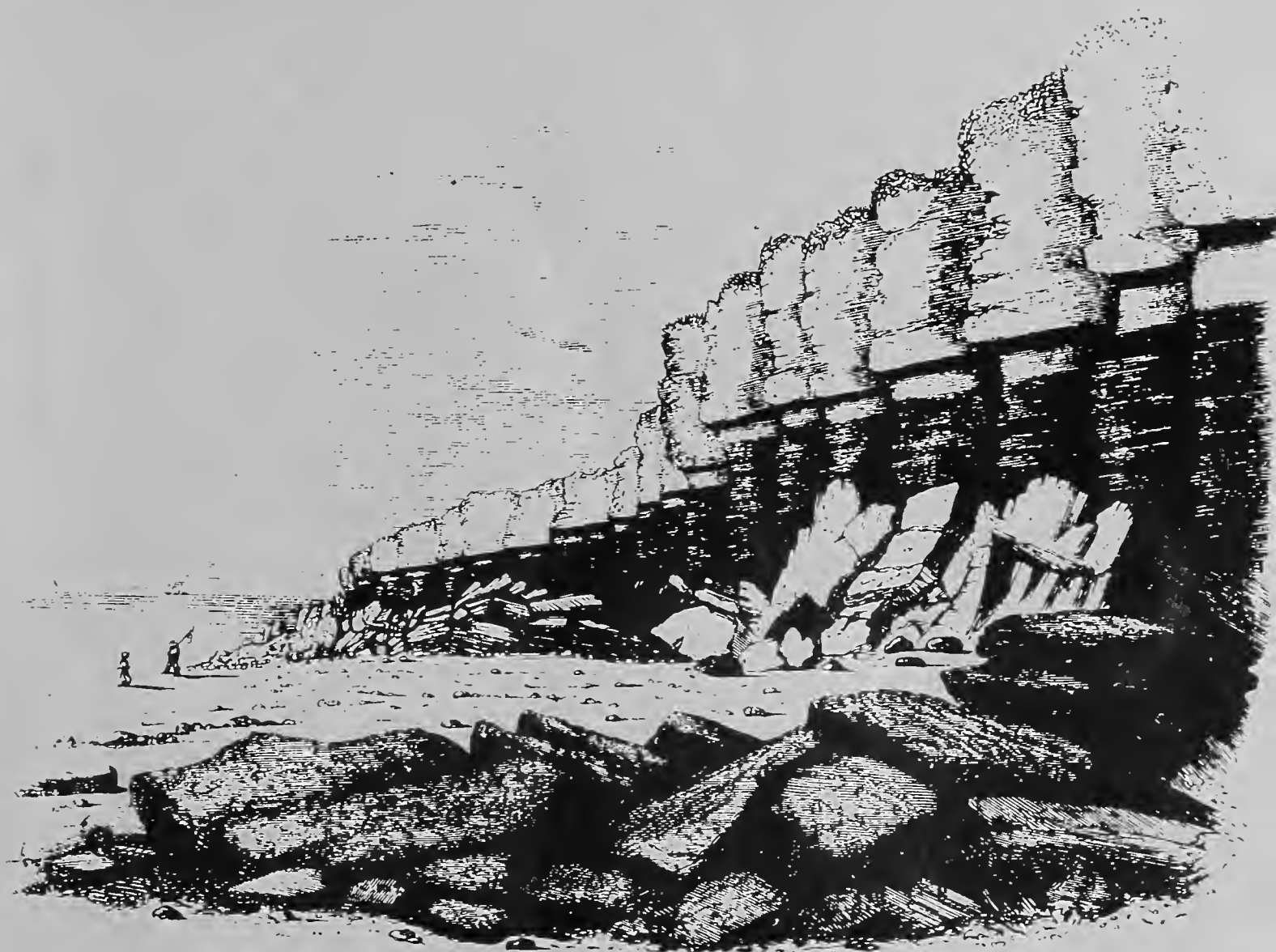
Visitors are welcome to attend the meetings and may apply for election to the Society. For further details write to the Secretary, Castle Museum, NORWICH, NOR 65B.

Copies of this Bulletin may be obtained 60p (post free) from the Society at the Castle Museum, NORWICH, NOR 65B; it is issued free to members.

Also available at 75p (post free) is "The Geology of Norfolk", a 108 page book describing the geology of the county, reprinted by the Society in 1970; members of the Society may buy one copy only at 40p.

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BULLETIN OF THE GEOLOGICAL SOCIETY OF NORFOLK

No. 21

CONTENTS INCLUDE:

EDITORIAL

In this issue we publish the second Presidential
Address continuing and concluding the story of the
North Sea, and another article on Geology in education.
Further articles on the latter subject are being
prepared as part of a series. We have some new ideas on
stratigraphical relationships in the early Pleistocene,
an account of a new borehole and a detailed and
informative account of coastal erosion based on one of
the Society's field meetings. Articles on molluscs and
pollen from Aldeby, and mammals of the last interglacial
in Norfolk will appear in the next issue.

Bulletin No.22 will be issued in September 1972.
Contributions should be sent to me as soon as possible,
and no later than July 31, 1972.

Will contributors please note that manuscripts are
acceptable in legible handwriting, although typewritten
copy is preferred. In either case it would be a great
help if details of capitalisation, underlining, punctuation,
etc., in headings and references (particularly), could
conform strictly to those used in the Bulletin.
Illustrations intended for reproduction without re-
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limit only.

R.S.J.

THE HISTORY OF THE NORTH SEA

(a summary of the Presidential Address for 1970,
delivered January 14, 1971)

B. M. FUNNELL*

The Tertiary Setting

At the end of the Cretaceous times the North Sea
Basin was defined in very much its present form. Since
then it has accumulated up to 3000 m of sediment in its
northern part, and up to 1000 m in the south (Funnell 1971).

At first the Palaeocene sea was relatively cool, as
witnessed by the presence of such bivalve molluscan genera
as Arctica and Macoma in the Thanet Sands of the London
Basin. During the Eocene, however, conditions became
sub-tropical, at least in the S.W. part of the North Sea.
At that time the Wealden Island was not present, and the
London and Hampshire Basins jointly accumulated muddy
sediments on the N.W. shore of an otherwise clear and
broad straits opening directly into the Atlantic. These
straits were bordered on their S.E. side by the lagoons
and mainly clear seas of the Paris Basin. Along the
shores of the straits, and extending into the S.W. part of
the North Sea, lived sub-tropical marine forms such as
large bivalve and gastropod molluscs (including volutes
and cowries), and larger Foraminifera; onshore palm trees
flourished, whose remains are now regularly washed from
the London Clay cliffs of the Isle of Sheppey. Further into
the North Sea, in the equivalent deposits of Denmark, the
sub-tropical influences are less evident.

Earth movements along the line of the English Channel
led to the raising of the Weald anticlinorium and other
structures in southern and south-eastern England from
middle Oligocene times onwards, and deposition in the
London, Hampshire and Paris Basins ceased. Restricted
interchange of Atlantic with North Sea waters was probably
the inevitable consequence of closure of the Lower Tertiary

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Anglia, NORWICH

straits, and this is reflected in the cooler water
molluscan assemblages found in the North Sea during the
Miocene. Nevertheless these were still of warm temperate
aspect, reaching an indication of maximum warmth in the
Middle Miocene. At that time sea-level probably topped
the raised Chalk cuestas to open broadly into the S.W.
North Sea from the Atlantic once more. Conditions
continued to be rather similar up to and including the
Pliocene, although by this time the over-riding effects
of world-wide climatic deterioration were already beginning
to become apparent, and were soon to affect drastically
both faunas and sea-level in the North Sea.

Plio-Pleistocene Events

Pliocene deposits in eastern England, Belgium and the
Netherlands, and under the central southern North Sea,
include a facies containing abundant bryozoans, well-known
in parts of the Coralline Crag. Such bryozoans need a
solid substrate on which to grow, and the presence of their
remains in cross-bedded deposits such as the Coralline Crag
implies post-mortal transport, and incorporation into
hydraulic dunes or sand waves on the sea floor away from
their point of origin. At the present day byrozoans grow,
and their remains are produced prolifically, on the sea
floor due west of Brest in the Western Approaches to the
English Channel. A broad belt containing their abundant
remains, albeit progressively diluted with molluscan shells,
extends N.E. into the English Channel, between and beyond
Start Point, Devon and the Channel Islands (Boillot 1965).
During the Pliocene the Atlantic probably still extended
broadly across the Chalk Downland area of southern England
into the S.W. North Sea. Bryozoans, existing in life on a
current-swept Chalk sea floor, for instance around the
Wealden Island, may well have been re-distributed after
death into a belt of hydraulic dunes extending into the
S.W. North Sea. Pliocene conditions in southeastern England

and the S.W. North Sea would therefore have compared with those in the Western Approaches and the western English Channel at the present day.

An additional analogy between these two areas is provided by the deep, S.W. - N.E. trending troughs, cut in Chalk and infilled by Pleistocene marine deposits, which exist under East Anglia at the present-day. These troughs are up to 45 to 50 m deep and sometimes over 30 km long (Fig. 1.) In the English Channel at the present day (Boillot 1963) there are three similar troughs, excavated in Chalk in the zone between Start Point, the Channel Islands and the Cotentin Peninsula. They are, with their approximate dimensions:

Central Trough	100 m deep;	165 km long,	6.5 km wide,
Pluteus Trough	20 m deep;	25 km long,	2.3 km wide,
La Hague Trough	50 m deep;	15 km long,	1.8 km wide,
(and for comparison			
Stradbroke Trough	45 m deep;	30 km long,	6.4 km wide)

The analogy between the East Anglian and Channel troughs is striking. Both are excavated largely in Chalk, and both traverse or are adjacent to tracts of bryozoan shelly sands, but are not infilled by them. The origin of neither is clear. The East Anglian troughs have been attributed to tectonic movements involving folding (Woodland 1946), but the higher yields of groundwater obtained from the Chalk between troughs can be just as easily explained in terms of a topographic origin, and S.W. - N.E. trends are not elsewhere typical of East Anglia structures.

Whilst most of the East Anglian troughs appear to be open to the N.E. this may be the result of eastward tilting towards the North Sea during the Pleistocene. The Stradbroke Trough is clearly still closed at both ends. An origin as a 45 to 50 m deep river valley is therefore unlikely, and, what is more, recent boreholes into these
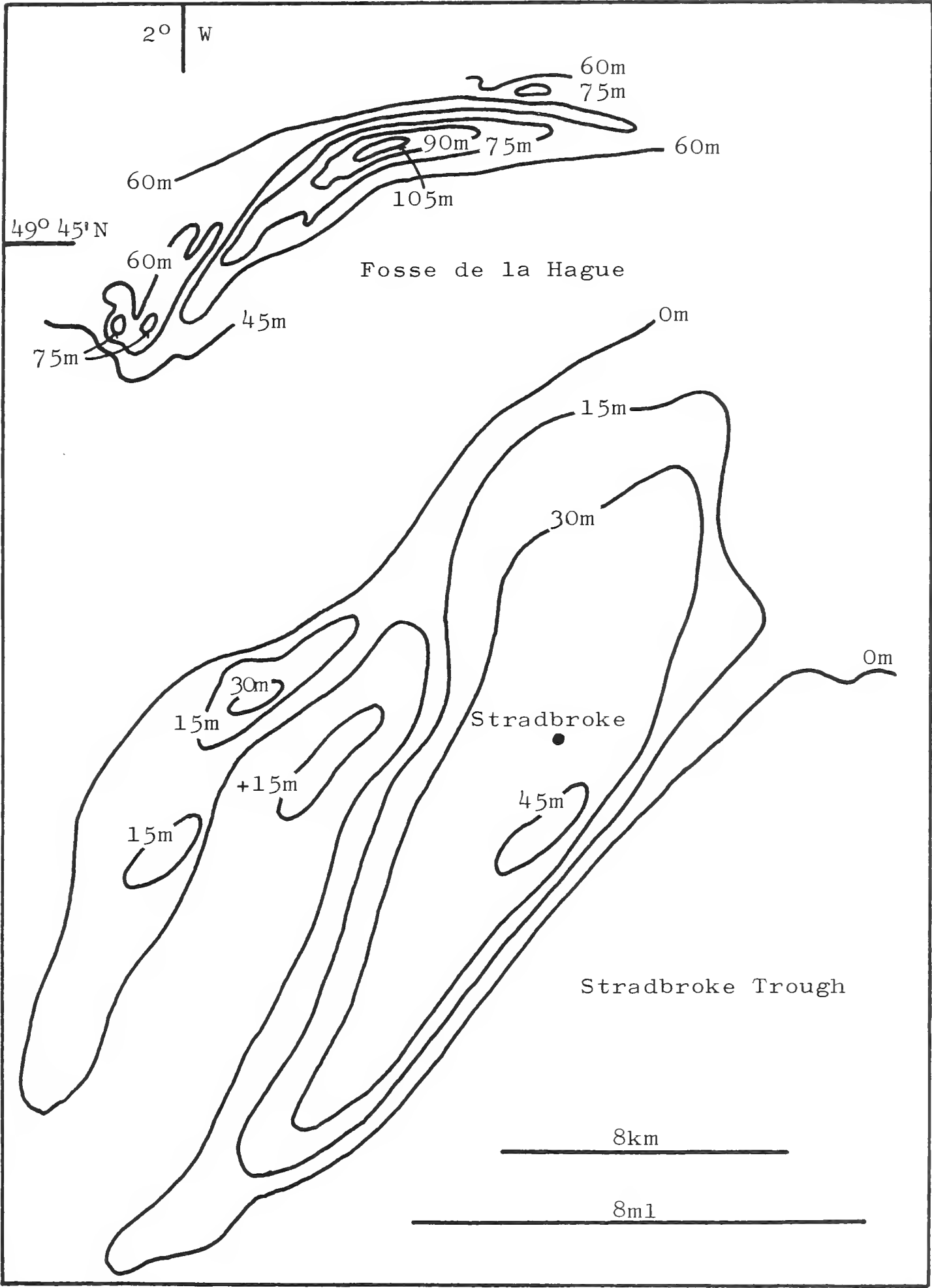
Fig. 1.   Comparison of the Plio-Pleistocene Stradbroke
          Trough with the La Hague Trough (present-day
          English Channel)

troughs (Lord 1969A,B, 1972) have not revealed any sign of freshwater or terrestrial deposits in the early stages of their infilling. These considerations bring us back to the analogy with the English Channel troughs.

Unfortunately no satisfactory explanation of the English Channel troughs is itself yet forthcoming. Four main explanations have so far been promulgated (Boillot, Bouysse and Lamboy 1971):

(a)   that they are drowned river valleys (but they are closed at both ends),

(b)   that they are tectonic valleys (but only general relation to structural trends established),

(c)   that they have been excavated by present-day tidal currents (but distribution of strongest currents not related to position of troughs),

(d)   that they are drowned Karstic forms (but dimensions of the Central Trough would be exceptional).

None of these explanations are wholly satisfactory for the reasons stated. However it may be surmised that in their present form, lacking deposits and being closed at both ends, they are at least maintained by the strong tidal currents active on the floor of the English Channel. A similar situation may be envisaged for the East Anglian troughs, which may therefore have originated and been maintained contemporaneously with the Pliocene Coralline Crag, when the North Sea was probably still broadly open to the S.W. across the dip slopes of the Chalk cuestas. They probably continued to be kept swept clear of any sedimentary infilling during the earliest part of the Pleistocene, but the falling sea-level generally associated with the regressive marine deposits of the Red Crag may have led to their infilling. Certainly the oldest deposits in the Stradbroke Trough appear to be of early Red Crag age, with rapid infilling by Red Crag

deposits reworked from elsewhere at a later stage in the
infilling process (Beck, Funnell and Lord 1972).

Whatever the precise origin and mode of infilling of
the East Anglian troughs the subsequent pre-glacial
history of the North Sea appears to reflect the severance
of the southwestward link with the Atlantic Ocean by a
general fall in sea-level. After Red Crag times warm
temperate species of foraminifer and mollusc, which
probably entered predominantly by the S.W. route, are far
less abundant. Those few species still found in the
Ludham Crag may have migrated, or been maintained by
migration, around the north of Scotland before conditions
become too rigorous. Thereafter boreal or arctic forms
predominate. Also generally thinner shells may reflect
less active ingress of water from the open ocean, and
relatively higher freshwater inflows leading to rather
reduced salinities, after the closure of the S.E. England
straits. In this shallow southern North Sea, strongly
influenced by sediments from the Rhine-Meuse and the
Thames, several climatic oscillations and minor
transgressions and regressions of the sea are recorded
(West 1961) before the definitive onset of glaciation.
These are reflected in the difficult to interpret and
complex deposits of the Norwich Crag and Cromer Forest
Bed Series (West 1972).

Glacial History

The glacial history of the North Sea is well
represented in deposits found on its margins in Norway,
Denmark, the Netherlands, Belgium and the United Kingdom,
but only recently have investigations of these deposits
on the floor of the North Sea been commenced.

A pioneering, yet comprehensive and well-documented
account is that of Oele (1969), who describes the sequence
of sediments in the S.E. North Sea off the coast of the
Netherlands. The succession he recognises commences with

the ELSTERIAN glaciation which is represented by the
Peelo Formation comprising fluvioglacial clays.   The
succeeding <u>Holsteinian</u> interglacial episode is a period
of non-deposition on this part of the floor of the North
Sea, contrasting with the marginal marine deposits of the
Nar Valley, Clacton-on-Sea, etc. found on shore.
Relatively shallow-water, marine deposits of this age
have however been found in the Inner Silver Pit in the
western North Sea (Fisher, Funnell and West 1969).   The
following SAALIAN glaciation is represented by the Drente
Formation, which consists of a boulder clay of
Scandinavian origin, and was a period of erosion of the
Dogger Bank.   The <u>Eemian</u> interglacial was again a period
of non-deposition on the bed of the S.E. North Sea, but
again marginal marine deposits, e.g. March Gravels,
Morston Raised Beach and the Eemian deposits themselves,
are well known on shore.   The final, WEICHSELIAN glaciation
is represented by the Twente Formation which consists of
lower and upper fluvial clays with an intervening wedge of
fluvio-periglacial coversands.

   The dominance of glacial over interglacial deposits
in the history of the late Pleistocene of the southern
North Sea indicates how much present sedimentary patterns
may have been determined by events in the latest
glaciation.

   ·In the S.E. North Sea the process of recovery from
the last glaciation led to the following sequence of
deposits:

Preboreal (up to 9,600 B.P.) Lower Peat

Boreal   (up to 8,000 B.P.) Elbow deposits;   freshwater
     clays, passing up into brackish-marine clays and
     finally sands.

Atlantic (up to 5,300 B.P.) no deposits recognised

Subboreal (up to 2,700 B.P.) no deposits recognised

Subatlantic (up to present-day) Young seasand, in which

the dynamic bed forms relating to present conditions
are developed. These reflect both the present tidal
current pattern and sources of supply of sediment in
the southern North Sea.

The entire Postglacial sequence reflects a transition
from terrestrial or freshwater conditions on the bed of
the southern North Sea, at the end of the last glaciation,
to fully marine conditions at the present time.

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GEOLOGY IN A COLLEGE OF EDUCATION

M. BRADSHAW*

A tutor in a college of education obtains a wider view of the educational field than the individual school teacher, and it is exciting to see the way in which geology is becoming an integral part of the curriculum in so many schools. This process is reflected in the increasing numbers and calibre of students applying for places in the colleges which offer courses in geology leading to honours degrees in education. There are now at least six such colleges; some of these, together with an increasing number of university institutes, offer geology as a method option in the postgraduate certificate course.

Mr. Evans, in his contribution to the September 1971 issue of this journal, was correct in saying that the time has now arrived for an appraisal of the concepts and methods implied in the geology syllabuses taught in the schools. The subject is attaining a status of acceptability, and it must now begin to adopt a more rigorous framework which will make it educationally viable. Those of us working in colleges of education have a privileged position of being able to survey, and to participate in, the developments taking place at the moment.

The most immediate challenge comes from our students teaching the subject in schools. What is the best way to approach the teaching of geology? Where can they obtain the supplies of necessary materials? The topics we discuss with them range from the philosophical working basis of the subject to the practical details of organising a course in the school context. We encourage them to place an emphasis on the field observational basis

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of the subject, linked closely to work in the laboratory
or classroom. Our ideas are being refined continuously
in the light of ever-widening experience, and will
shortly be distilled in 'Teaching Geology', a book which,
it is hoped, will appeal to established teachers as well
as our own students. David and Charles hope to publish
this in 1973.

Most of us would agree that the most significant
event in the progress of geology teaching in schools in
recent years has been the founding of the Association of
Teachers of Geology, and my colleague, Mr. A. J. Dunk, is
now the Honorary Secretary. The Association's membership
is approaching the 700 mark, it has a lively journal
entitled simply, 'Geology', and the annual conference is
a 'must' for as many teachers as can possibly attend. The
conferences have been held at Keele, Sheffield and
Bristol, and combine lectures from eminent geologists,
with field excursions, discussions and displays of
materials and books. Perhaps their most important
function is as a forum for the exchange of views on
teaching problems, and the gatherings must be unique in
that they bring university professors together with
primary school teachers. The Association has been
established only for a few years, but has undertaken
surveys of the present examination syllabuses, the
reports of which have been received by the examination
boards. The boards in their turn have requested ATG
nominations for membership of their geology panels.

Other important developments in which we are
involved concern the place of geology in the overall
school curriculum. The close relationship which exists
in many schools between geology and geography has been
criticised, but we must always be grateful to so many
geographers for introducing and teaching our subject

for so many years. And yet geology has its base in close
observation and measurement, leading to the formulation
of theories and the application of these in practice. In
short, it is linked essentially to physics, chemistry and
biology. Any discussion of teaching methods must be
related to developments in these subjects. For this
reason we have been keen to participate in the Schools
Council Integrated Science Project, which is designed for
the more able pupils at GCE Ordinary Level, and will lead
to a double O-level pass for the candidates. Aspects of
earth science are established in this course, and the
challenge provided by the need to devise investigations
and experimental approaches to the subject has been most
stimulating.

It seems a logical outcome of such work that further
projects of this nature should be developed at Sixth Form
level. It is our experience that teachers in school find
it difficult to assemble the resources they need for
their courses, and so curriculum development projects are
not mere gimmicks but have real purpose. Teachers of
experience are provided with the time and money to think
through aspects of the curriculum and are able to advance
the effectiveness of teaching in their subject. Our
ideal at the moment is a course in the earth sciences
(i.e. broadly including geology, meteorology and ecology).
It seems more appropriate to do this than to press the
claims of yet another single subject and thus to
emphasise the arbitrary boundaries between subjects. One
must of course guard against superficiality when
including a wider range of subject matter, but the aim of
such a course would be to emphasise the working
principles rather than the mere acquisition of facts. It
seems that the field sciences possess an inherent
attraction for students, but there is a need for a more
rigorous basis than is provided at the moment by a

largely descriptive physical geography, the normal run
of environmental studies, or emotive approaches to
pollution and conservation.

Geology is now being seen as a useful integrating
element in junior school science courses, and success has
been obtained with its introduction as a basic subject in
ESN schools. The stress on outdoor observation, together
with the emphasis on the laboratory processing of results,
appeals at these levels. The history of the earth's
development, and the discovery of riches in the minerals
of the Earth's crust, are both sources of immediate
interest.

In addition to the consideration of what is happening
in schools we have to teach the subject to our own
students, and this involves mounting courses which take
them to a joint honours degree standard. This means that
we have a heavy and demanding teaching load, equivalent
in time to that of a school teacher. The range of our
courses and the fact that our students are intent on a
future teaching career means that we attempt to develop
our own teaching techniques in this light. When I took
up the post I lectured to the groups in a fairly traditional
manner, but found that the students imitated this during
their teaching practice. Now I attempt to teach even the
more advanced material in the sort of way in which it can
be introduced to the school classroom. One's ingenuity
is often stretched, but the emphasis on a practical,
observational and even experimental approach whets the
students' interest and sharpens their wits to engage in
a discussion of the issues involved. The lecture room
full of students is involved, just as the classroom should
be in school.

Yet another aspect of the educational process in
which one becomes involved is the examination system. It
is all very well to grumble about the present system

blighting the school curriculum and the progress of individual pupils, but it is more positive and effective to take some part in making it more suited to the system one would like to see. Through the Association of Teachers of Geology, and our position as college of education lecturers, we have become involved in the development of CSE and GCE syllabuses and assessment. It is encouraging to see the more progressive examination boards producing new, more interesting syllabuses, together with suggestions on the teaching of these and the conduct of field excursions. In this way the examination becomes a logical outcome of the course rather than an arbitrary chopping block, the fear of which has nullified the educational value of the course.

Teaching, writing, examining and thinking about the place of geology in schools is a full-time occupation, and extremely demanding. At times my colleague and I get very tired, but we never lose our sense of excitement at the way in which this situation is developing. New vistas open with developments outside the college, and our own students make their own contributions, whilst our contacts with the schools provide further fuel. We trust that the imminent re-organisation of the colleges of education will not affect the role which we are able to play.

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THE STRATIGRAPHICAL POSITION OF THE NORWICH CRAG IN RELATION TO THE CROMER FOREST BED SERIES

R. G. WEST*

During the last few years the stratigraphy of the Cromer Forest Bed Series had been clarified by the application of pollen-analytical methods to the coastal exposures from Weybourne to Corton. Table 1 summarises the provisional stratigraphical results (West and Wilson 1966).

TABLE 1: Provisional Stratigraphy

Stage	Deposit	Environment	Formerly identified by C.Reid as:
Lowestoftian	i Till	Glacial	Cromer Till
	h Mossy silts, sands	Cold freshwater	Arctic Freshwater Bed
	Ice-wedge casts and involutions	Permafrost	
Cromerian	g Silts, sands	Temperate estuarine, marine	Leda myalis Bed, Forest Bed(estuarine)
	f Soil	Temperate	
	e Muds, peats	Temperate freshwater	Upper Freshwater Bed
Beestonian	d Silty marls	Late-glacial freshwater	
	c Silts	Cold freshwater	Arctic Freshwater bed
	b Gravels, sands, clay-conglomerates	Cold	Forest Bed (estuarine)
	Ice-wedge casts and involutions	Permafrost	
Pastonian	a Silts and sands	Temperate estuarine, marine	Weybourne Crag

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Since 1958 a number of pollen samples have been
collected from the Norwich Crag (in the sense of Reid
1890) in Norfolk and Suffolk. They include samples from
open section, samples from shallow auger holes, and from
deep boreholes carried out for water supply purposes.
The resulting analyses suggest a new interpretation of
the Norwich Crag and its relation to the Cromer Forest
Bed Series. We shall first summarise the new evidence,
and then consider its bearing on Crag stratigraphy.

The following sites have yielded the evidence to be
discussed here. Their locations are shown in Fig. 1, and
approximate O.D. heights are given in brackets were
possible.

1. West Runton.   Estuarine silts of Pastonian
                      age (-1m.O.D.).

2. Sidestrand.   Estuarine silts and marine
                      shelly sands of Pastonian age
                      and Beestonian age (contorted
                      by ice movement).

3. Paston.   Estuarine silts. Type area
                      for Pastonian temperate stage
                      (-3m.O.D.).

4. Ludham.   Estuarine silts overlying the
                      Baventian silts and clays (West
                      1961) (-6m.O.D.).

5. Outney Common,
    Bungay.   Estuarine silts and shelly
                      gravels (-3m.O.D.).

6. Thorpe
    Aldringham.   Shelly sands with silts (+3m.O.D.).

7. Aldeburgh.   Shelly sands with thin silts
                      (+4m.O.D.).

8. Chillesford.   Sands with few shells and thin
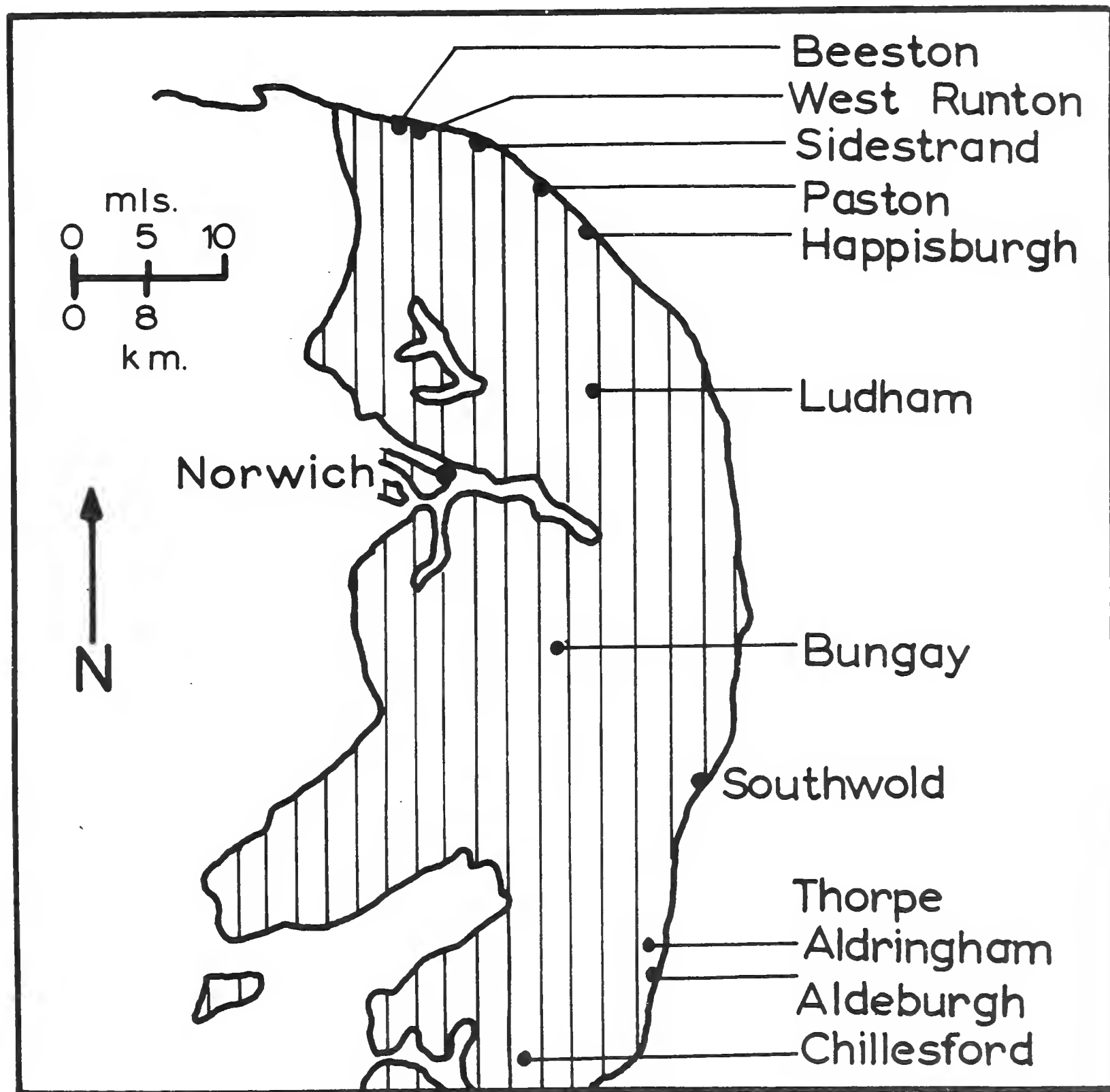   silts (+9m.O.D.).

Fig. 1.   Location of Sites

At the first three sites, the sediments mentioned are of
Pastonian age. They all have temperate pollen spectra
of the type exemplified in Fig. 2. A series of pollen
spectra from zone L5 of the Ludham borehole (West 1961)
and from a borehole at Outney Common, Bungay, have the
same type of spectrum, and so do the pollen samples
taken from open section at sites nos. 7 and 8, and from
a shallow borehole at site no. 6. Spectra from these
sites, nos. 4 to 8, are also shown in Fig. 2.

    The similarity of all these spectra will be noted.
But they are dissimilar to the temperate spectra from the
Cromerian on the one hand, and from the temperate stages
of the Early Pleistocene (Antian, Ludhamian) on the other
hand. The major dissimilarity to the Cromerian lies in
the fact that the estuarine facies of Cromerian contains
much Abies pollen as well as that of Carpinus. It should
be mentioned that at West Runton, the type site for the
Cromerian, the Pastonian is stratigraphically distinct
from the Cromerian, and is separated from it by an arctic
plant bed and permafrost features. The dissimilarity with
the earlier temperate stages lies in the absence of Tsuga
pollen, characteristic of the Antian and Ludhamian temperate
stages.

    A conclusion which might be drawn from the pollen
spectra obtained from the sites under discussion is that
the marine and estuarine deposits concerned are the
products of a single marine episode. The similarity of
the O.D. heights of the different sites tends to support
this conclusion. In time this transgression must be
placed between the Beestonian and Baventian cold stages.
The evidence for this placing of the marine episode is
the superposition of Beestonian sediments at West Runton,
Sidestrand, and Paston, and the infraposition of the
Baventian at Ludham (West 1961).

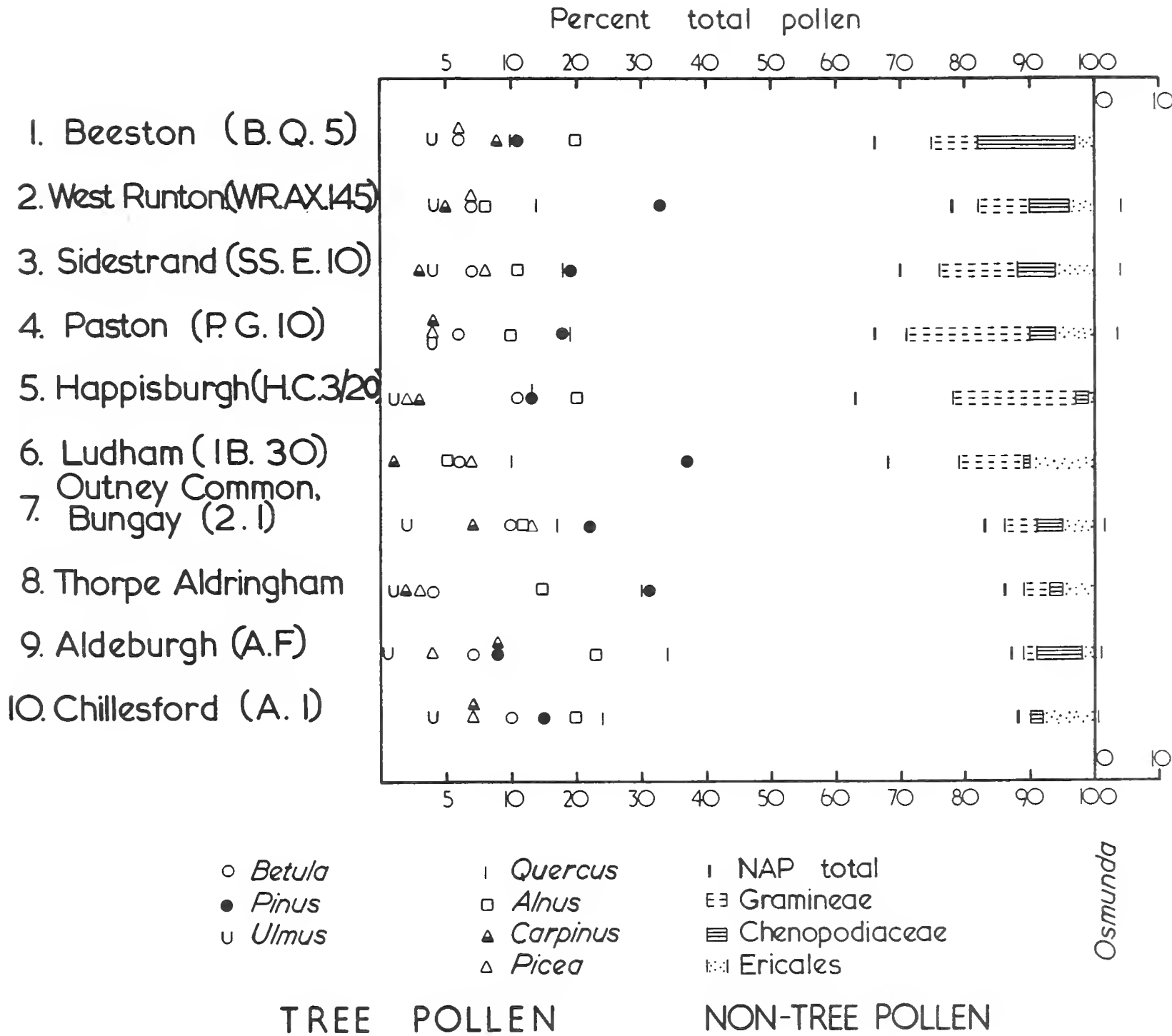   Now the shelly gravels or sands from which the pollen

Percent total pollen

1. Beeston (B. Q. 5)

2. West Runton (WR.AX.145)

3. Sidestrand (SS. E. 10)

4. Paston (P. G. 10)

5. Happisburgh (H.C.3/20)

6. Ludham (1B. 30)

7. Outney Common, Bungay (2. 1)

8. Thorpe Aldringham

9. Aldeburgh (A.F)

10. Chillesford (A. 1)

○ *Betula* ｜ *Quercus* ｜ NAP total
● *Pinus* □ *Alnus* ⊟ Grammeae
∪ *Ulmus* ▲ *Carpinus* ▤ Chenopodiaceae
  △ *Picea* Ericales

Osmunda

TREE POLLEN   NON-TREE POLLEN

Fig. 2. Pollen spectra

samples come at Bungay, Thorpe Aldringham, and Aldeburgh
are the classic sediments of the Norwich Crag, while
those at Chillesford have been described as Chillesford
Clay and Crag, and those at Sidestrand as Weybourne Crag.
We therefore conclude that the Norwich Crag, Chillesford
Crag and Weybourne Crag at the sites studied are probably
all deposits within the temperate Pastonian stage. To
the north the sediments overlap basal stone beds on the
frost-shattered chalk, probably of Baventian age. To
the south the sediments overlap the Red Crag and Coralline
Crag in the Aldeburgh region. We thus have the picture of
a marine transgression overlapping the older Crags in much
of the coastal Crag area in East Anglia. This trans-
gression may also be associated with the beach gravels of
the Westleton Beds (Hey 1967). These Pastonian trans-
gression deposits probably overlie unconformably the
Baventian silts and clays, as the latter are absent in
many sections and boreholes. They are overlain on the
Norfolk coast by freshwater regression deposits and,
unconformably, by the freshwater arctic deposits of the
Beestonian stage. Further, there is some indication from
the O.D. heights of the sites mentioned that there has
been upwarping of the Pastonian sediments in the southern
margin of the Crag basin relative to the central part of
the basin.

Much more work is required before the stratigraphy
of the different shell beds considered here and their
overlapping relation to the older Crags can be made out
in detail. But, meanwhile, the evidence described here
makes the consignment of the various Crag horizons
mentioned to the Pastonian stage a definite possibility,
which will considerably simplify the Crag sequence of
East Anglia.

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A PRELIMINARY ACCOUNT OF A RESEARCH BOREHOLE
AT SYLEHAM, SUFFOLK

A. R. LORD*

Initial accounts of our previous research boreholes
undertaken in an investigation of the Lower Pleistocene
have already appeared in the Bulletins of this Society.
The present note describes the findings of a fifth
borehole, the last in the current series. Some results
from the Stradbroke Borehole (UEA 3) will appear shortly
in the Geological Magazine.

Borehole UEA 5. High Elm, Syleham, Suffolk (TM 2095 7833)
- located beside the East Anglian Water
Company's pumping station

Drilled in October, 1970. Surface level 139.48'
(42.51m) O.D. The borehole was made close to the pumping
station, where a number of boreholes had been drilled by
the East Anglian Water Company for water supply purposes.
The earlier boreholes provided valuable stratigraphic
information and, particularly important, a number of
samples which included a peat from 105-108' (32.0 - 32.9m.)
below surface and sands containing excellent assemblages
of foraminifera. The water bores gave the following
general succession:

0' - 3'	(0 - 0.9m.)	Top soil and brown clay
3' - 21'	(0.9 - 6.4m.)	Blue clay
21' - 55'	(6.4 - 16.7m.)	Sand with a little gravel
55' - 69'	(16.7 - 21.0m.)	Gravel with a little sand
69' - 91'	(21.0 - 27.7m.)	Fine brown sand
91' - 100'	(27.7 - 30.5m.)	Gravel with flints
100' - 105'	(30.5 - 32.0m.)	Green sand
105' - 108'	(32.0 - 32.9m.)	Peat
108' - 181'	(32.9 - 55.1m.)	Green sand

(continued)

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181' - 185' (55.1 - 56.3m.) Sandy brown clay
185' - 216' (56.3 - 65.8m.) Blue clay
216' - 222' (65.8 - 67.6m.) Hard green sand
222' - 231' (67.6 - 70.4m.) Blue clay and flints
231' (70.4m.) Chalk
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The succession found in the research borehole is shown in Fig. 1 and is generally comparable with earlier findings, although it should be noted that since the water bores were drilled by a reversed circulation technique their data is less reliable. The grey and brown chalky boulder clay at the top of the sequence is thought to be Lowestoft Till, although the till encountered in the Stradbroke and Hoxne Boreholes (UEA 3 and UEA 4) was more uniformly blue-grey in colour. Beneath the till occurred coarse gravels and sands, and at 71' (21.6m.) depth sands which were clean washed with small pieces of chalk, which may indicate that they are "Corton Beds" and that the coarser material above is of glacial origin. At 100' (30.5m.) depth the sands became green and are interpreted as the Norwich Crag Series even though shell material did not occur above 139' (42.3m.). Beneath this depth the quantity of shell increased but complete shells were never very common. Below 193' (58.8m.) silty clay layers became common, but it was not before a depth of about 220' (67.0m.) was reached that it was possible to consider the argillaceous material as forming a unit of hard silty clay. A thin band of flints was found to rest on the chalk surface which was reached at a depth of 229' (69.8m.) below surface.

The research borehole proved a good sequence of 'Crag' sands and clays between 100' (30.5m.) and 229' (69.8m.), which first samples show to contain fine assemblages of diatoms and foraminifers. It was unfortunate, but not unexpected, that the peat layer was not found but the
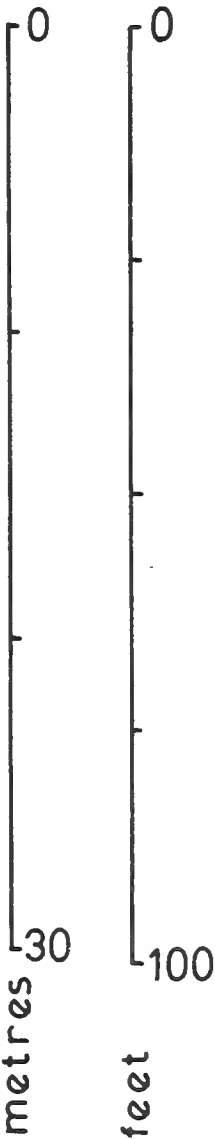
NORFOLK

Bungay

Diss

Syleham

SUFFOLK

0   km.   25
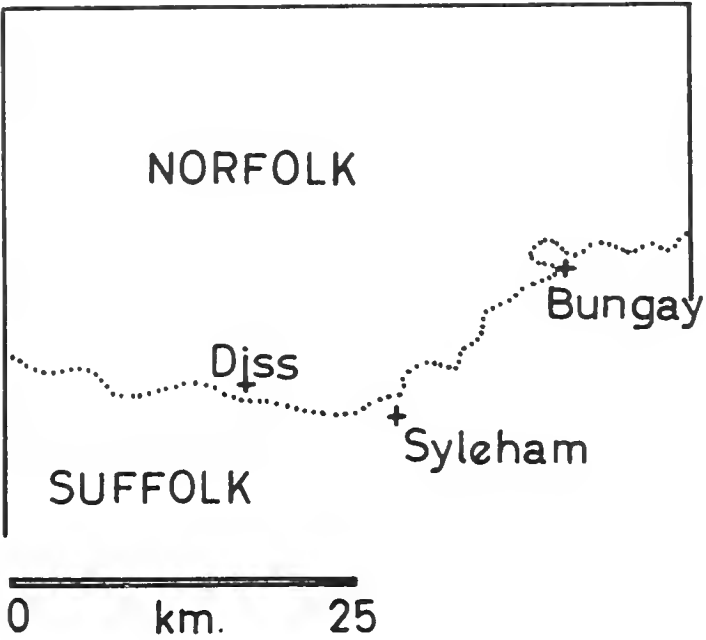
SIMPLIFIED LOG OF THE RESEARCH
BOREHOLE AT SYLEHAM, SUFFOLK.

139.48'O.D.
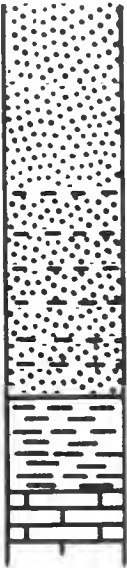
UEA 5

Key:

| △ | boulder clay |
| sand |
| clay |
| gravel |
| chalk |

0   0

metres   feet

30   100

Fig. 1.   Log of research borehole at Syleham, Suffolk
          (UEA 5)

foraminfers may provide some clue as to conditions at that time.

Acknowledgements

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REPORT ON A FIELD MEETING TO THE NORFOLK COAST AT
YARMOUTH AND OVERSTRAND

S. J. CRAIG-SMITH and G. CAMBERS*

On Sunday 19th September 1971 a field meeting was
held to examine some of the erosion problems along the
Norfolk coast. The party assembled by the yachting
pool (bottom right of Fig. 1) on Gorleston Beach at 11
a.m. and was given an outline of the erosional history.

Gorleston beach lies immediately south of Yarmouth
harbour entrance which is the outflow of the rivers Yare,
Waveney and Bure, the only major river system in Norfolk.
The beach extends south from the harbour to Yarmouth
borough boundary, a distance of approximately 1.7
kilometres. Its width today varies from about 80 metres
at its northern end to 50 metres at its southern end
(limit of low water spring tides) but this is less than
half its width in the early 1960's. Backing the beach
for its entire length is a concrete wall and behind that
Gorleston cliffs, 20 metres high, artificially sloped and
turfed.

Prior to 1962 Gorleston beach showed little sign of
erosion. Beach levels dropped after severe storms but
the beach was soon restored to its original volume.
Since that date however, there has arisen a serious
problem of erosion which shows no sign of abating. By
1965 erosion had become sufficiently serious for the
Borough Engineer to consult the Hydraulics Research
Station which conducted a survey the following year
(Hydraulics Research Station 1966). In December 1969
14,000 cubic metres of sand was injected onto the beach
near the yachting pool (a remedial measure suggested by
the Hydraulics Research Station) but this had only a
temporary effect. In 1970 the Borough Engineer asked the
School of Environmental Sciences at the University of East
Anglia to carry out a three year research programme

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Fig. 1. Aerial view of coast - Gorleston to Caister

(Craig-Smith 1971A, B, C) into all the environmental
factors, not only at Gorleston, but along the entire
coast from Winterton in Norfolk to Benacre in Suffolk.
(This project is also being sponsored by Lothingland
Rural District Council and Lowestoft Borough Council.)
As part of the analysis early maps of Gorleston beach
were consulted.

A number of interesting points arise from an
examination of old maps of Gorleston beach. The
earliest reliable map of the beach is the first edition
of the O.S. 6 inch map (1:10,560) surveyed in the early
1880's. Earlier maps exist but their scale is too
small and their cartographic accuracy must be regarded
with caution (Carr 1962). On this map the high water
mark is shown landward of its present position in spite
of the very considerable landward advance of this water
mark over the last few years. The 1900's edition of the
same scale map shows the high water mark to have
advanced seaward 75 metres immediately south of the
harbour mouth. The 1930's edition shows another
advance putting the high water mark 100 metres seaward
of its 1880's position. Accretion then slowed down
but continued, for the 1950's edition shows high water
mark 110 metres seaward of its first recorded position.
Since the 1950's the high water line has receded very
rapidly reverting to its 1880's position in under 20
years (Fig. 2, map 1A). This suggests that on
Gorleston beach there has been a long phase of accretion
(70 years) followed by a recent trend of very rapid
erosion (under 20 years and pronounced only in the last
10 years).

This cartographic evidence is supported by the
existence of a series of groynes recently exposed after
being buried in the sand since the 1890's. The
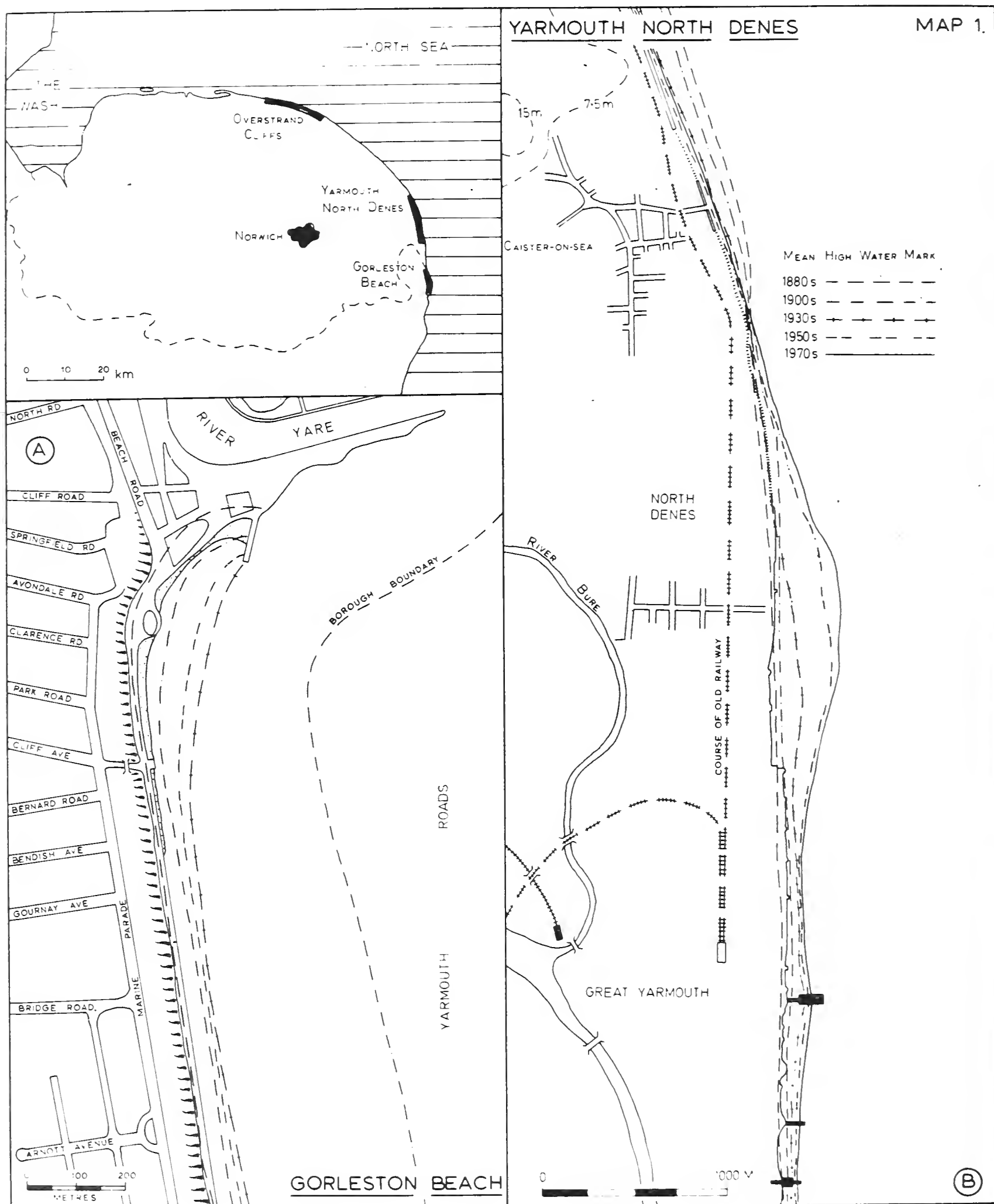considerable losses of sand in December 1970 finally

Fig. 2. Map of coastal changes - Gorleston to Caister

exposed these groynes. In the 1966 H.R.S. Report it
states ".....it has been suggested that a number of old
groynes lie buried in the beach." If the present
erosionary trend continues these groynes may soon be
washed away. These groynes however, indicate that beach
levels in the 1890's were no higher than they are today.

These findings pose a number of problems, the first
being why Gorleston beach accreted 110 metres between
1880's and 1960's. Secondly, after this accretion why
did erosion start in the early 1960's? The most generally
accepted answer, particularly held by local people, is
that the new South Pier to Yarmouth harbour is now in
solid concrete, whereas its predecessor was of an open
wooden structure which allowed sediment transport
southwards from Yarmouth beach. The fact that this new
pier was built in the early 1960's when serious erosion
first began could be more then coincidence, but other
factors so far ignored could all play a cumulative part.
The change in the offshore configuration (i.e. change in
position and depth of channels and sand banks), together
with the frequency of easterly winds within the last 10
years must all be examined. It is not possible at this
early stage to state exactly what process plays which part
in the accretional/erosional history of Gorleston beach,
but natural phenomena are rarely, if ever, a product of
just one process.

The party then went onto the beach to examine the
exposed toe piling of the yacht pond and the remains of
the old groynes exposed earlier in the year. An
examination was made of the pebbles on the beach and then
the party moved north to Yarmouth North Denes (top centre
of Fig. 1) outside the Iron Duke Hotel.

In marked contrast with Gorleston beach, Yarmouth
North Denes only 5 kilometres to the north is an area of

local continuous accretion showing a net gain of
approximately 2.25 million cubic metres of sand since
the 1880's (Fig. 2, map 1B). Between the 1880's and
1900's the beach was accumulating at 0.7 metres per annum,
but this increased to 2.7 metres between 1900 and and
1930's. Since the 1930's accretion has slowed slightly
but is still 2.5 metres annually. The sea wall
constructed in this area in the 1930's has never been
reached by the sea in normal conditions.

According to Robinson (1966) the reason for this
local accumulation lies in the offshore configuration.
Caister Shoal lies offshore; this is a long narrow sand-
bank trending towards the coast at the Denes area. Thus
sediment movement, which normally takes place parallel
with the shore, trends towards it at this point and then
wave action can move the sand onto the beach. After a
brief examination of the beach the party stopped for
lunch before proceeding to the North Coast.

The afternoon was devoted to a consideration of the
erosion problems on the cliffed section of the North
Norfolk Coast. The cliffs extend from Weybourne in the
west to Happisburgh in the east - a distance of 30
kilometres. They are composed throughout of glacial
material, and were deposited during the Lowestoft Stage
of the upper Pleistocene. The glacial material lies on top
of the Chalk, which dips to the east; hence between
Weybourne and Sheringham the cliff base consists of solid
chalk. At Sheringham the Chalk is at sea level, and so
disappears from view further east, except for occasional
exposure of the old chalk platform on the beach, when
sand levels are low due to erosion by waves.

The cliffs exhibit a considerable range, both in
composition and height. Many attempts have been made to
work out the geological succession - perhaps the number

of these attempts indicates the complexity of the field
evidence. One of the most detailed accounts is given
by J. D. Solomon in his paper of 1932. As regards cliff
height the range extends from 22 metres at Weybourne, to
a maximum of 70 metres at Trimingham, and declines again
to 10 metres at Happisburgh.

       This length of coast shows a picture of continual
erosion, unlike the coast further south where, as
explained in the morning, Gorleston beach has shown
phases of erosion and accretion at different times. The
erosion has been calculated from the changed coastline
position as shown on the 6 inch O.S. maps (1:10,560) over
the past 80 years. This provides us with a mean figure
of 0.8 metres retreat per annum. However, this figure
masks a considerable variation, and the following table
shows a more detailed picture of the erosion rates.

STRETCH OF COASTLINE	DISTANCE (km)	RETREAT RATE (m/annum)	CLIFF HEIGHT (m)
Weybourne - Sheringham	4.03	0.41	26.17
Sheringham - Cromer	5.08	0.43	30.00
Cromer - Overstrand	2.60	0.46	53.10
Overstrand - Trimingham	2.42	1.63	49.40
Trimingham - Mundesley	3.22	1.01	25.00
Mundesley - Happisburgh	9.80	0.94	21.32

       The cliffs from Overstrand to Trimingham show the
highest rates of erosion, and it is also here that the
cliffs attain their greatest height. However, before
concluding that these two facts are linked, one must
also take into consideration the relatively high retreat
rate of the cliffs between Mundesley and Happisburgh
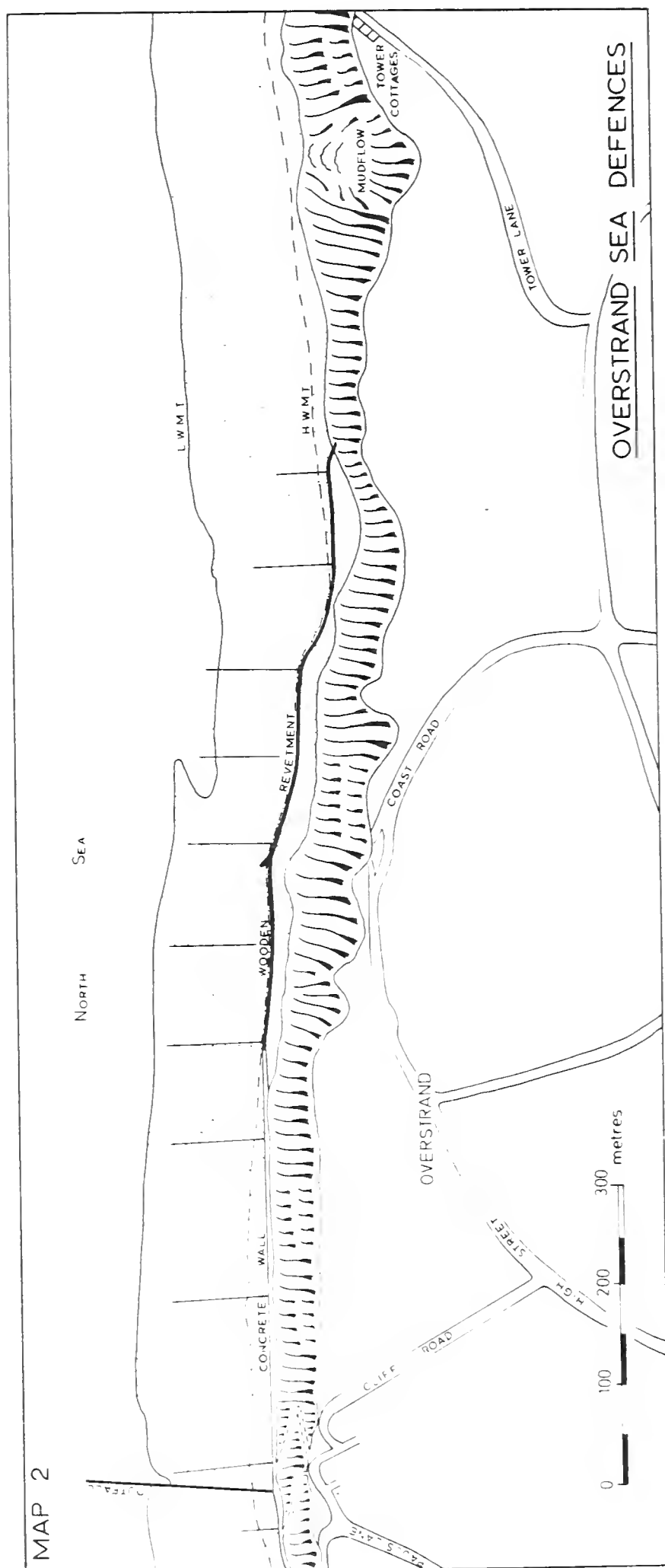(0.94 metres per annum) yet this is an area of very low

Fig. 3.   Overstrand sea defences

cliffs so therefore......? Hence we must conclude that
any relationship will inevitably be complex - including
such factors as types of erosion processes, geology of
the cliffs, beach height, and offshore configuration -
thus providing a multivariate situation which requires
complex analysis techniques. Present work is being
directed into evaluating the relative importance of these
factors.

The volume of material removed from the cliffs each
year is 750,000 cubic metres. This compares with the
figure of one million cubic metres per annum for the
erosion of the Holderness coastline - a 61 kilometre
length of cliffs in Yorkshire, again in glacial materials
(Valentin 1971). The material from both coastlines will
be deposited in the North Sea.

At Overstrand itself the erosion problems are
particularly severe. The most important factors causing
the high erosion here are the number of underground
streams issuing out of the cliffs (these help to initiate
cliff falls and mudflows), the inherent weakness of the
glacial material, and the low beach - which allows the
sea to reach the cliff base at high tide and to remove
any debris that has accumulated there. Thus this
represents an extremely efficient erosion system, with
a virtually constant supply and unimpeded removal.

The party examined the cliffs at Overstrand, and
discussed the attempts that had been made to defend them.
The coastal defence works (Fig. 3, map 2) consist of a
wooden revetment, which is designed to prevent the waves
attacking the base of the cliffs, and which together
with the groynes is meant to promote beach development.
In addition there is a concrete sea wall in front of the
village itself, and the remains of an old sea wall which
was destroyed in the 1953 storm surge are exposed on the

beach - for at present the sand level is very low. The second part of the sea defence scheme is concerned with an attempt to drain the cliffs - however, here problems are encountered due to the fluctuating nature of these underground streams.

Indeed the party observed a number of these streams emerging from the chalk erratics near the eastern end of the defences. It was also noticed that they were red coloured - due presumably to their iron content. Towards Sidestrand further streams were seen to emerge from the cliffs at many different levels.

As the party walked along the beach behind the defences, it was observed how previous high tides has scoured out the beach behind the revetments, so that now high tides can attack the cliffs themselves - thus emphasising the temporary nature of these defences. And indeed, from the east Overstrand may be observed to project out like a headland - this is the result of coastal protection at one point only, while adjacent sections remain unprotected and hence erosion is concentrated here - resulting eventually in a headland.

At one point, just west of Tower Cottages, Sidestrand (G.R. 258403) the party climbed up the cliff to view a large mudflow which had developed in the site of an old rotational slip (Fig. 4). Discussion ranged over the relative importance of cliff falls, mudflows, stream erosion and other processes taking place.

After this the party broke up. It had originally been planned to visit Mundesley where sea defence works have proved more effective, however time did not allow, so just a brief reference was made to this site.

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Fig. 4. Mudflow on site of old rotational slip - Sidestrand

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REPORT ON FIELD MEETING TO THE NORFOLK COAST
(Joint Meeting with the Conchological Society of Great
P. G. CAMBRIDGE*   Britain and Ireland)

The purpose of this meeting, on August 8th 1971, was
to examine and collect from a series of sands occurring
in the tills of the Norfolk Coast. The first of these was
at California Gap (TG 518417) where a series of sands
occur between two tills or boulder clays. Near the base,
these sands are often rich in shell fragments and members
collected a good representative series. The sand beds are
probably a northern extension of the Corton Sands. Many
of the shells are well known from the earlier Crag series,
such as <u>Scaphella</u> <u>lamberti</u> (Sowerby), <u>Turritella</u> <u>incrassata</u>
(Sowerby), <u>Astarte</u> <u>omalii</u> Lajonk, etc., but with them are
considerable numbers of <u>Macoma</u> <u>balthica</u> (Linné). The
'Cortonian' fauna has been the subject of much controversy
over the years and three possible origins have been
suggested:

1.   That the whole fauna lived in the area and that the
      'warm water' forms, which had been wiped out by an
      ice advance, re-occupied the area from elsewhere.
      In support of this argument certain species were
      cited which were not known in earlier Crag beds.
      One of these species has since been found in the
      Ludham Crag and others seem to have been based on
      small possibly immature forms, or protoconchs.
      Since the original specimens are not available, it
      seems best to ignore these earlier records and
      concentrate on accurate collecting.

2.   That the deposit was formed partly from the
      destruction of Crag beds of several ages during a
      temporary regression of the ice front and that all
      the shells are derived.

*258 Bluebell Road, NORWICH

3.   That some forms were derived from earlier Crag and
      that these are mixed with an indigenous fauna.
      Certainly the forms characteristic of the earlier
      Crags are usually very fragmentary and worn.

    . After driving over a large area of low-lying silty
ground, bordered by sand dunes, the next area of higher
ground was reached.   The party descended the cliffs near
Mundesley (Little Marl Point, TG 300378) in the hope of
locating shelly layers in the Gimingham Sands.   Although
this was unsuccessful, shell fragments were seen in a
typical boulder clay, including <u>Cardium</u> (<u>Cerastoderma</u>)
<u>edule</u> L, <u>Arctica islandica</u> (L) and <u>Macoma balthica</u>.   A
small chalk bluff at the base of the cliff was examined
and some members collected Maastrichtian Chalk fossils
here.

    The last stop was at West Runton Gap (TG 185431)
where the party first examined the sands in the large
basin to the west of the Gap.   The mode of formation of
these large sand basins is not fully understood;   they
may or may not have been formed at the same time as the
large spreads of Corton Sands to the south.   Near the top
of the basin a layer of large flints was seen and from
this a number of flat, rounded pieces of ironstone, a
piece of heavily mineralised fossil wood, and a fragment
of deer antler, were taken.   For about two metres below
this pebble bed the current bedded sands contain large
numbers of worn shells and shell fragments.   The majority
of the shells are the same species as those found in the
clays of the North Sea Drift but in addition Red Crag
shells such as <u>Nassarius reticosus</u> (Sowerby) form
<u>costatus</u> (Wood) have been found, as well as extremely thin
and fragile freshwater shells.   On this occasion an
example of the Cromerian <u>Valvata goldfussiana</u> (Kennard)
was found.   The ironstone, deer antler and freshwater
shells could all be from the Cromerian period.

For the remainder of the time available members split up into groups, to browse either on the dark humic clays of the Lower Freshwater Bed or on the Stone Bed of the Weybourne Crag. The former is exposed at the base of the cliffs and is the type site of the Cromerian, and yields a selection of plant material, freshwater shells, fish teeth, etc. The large flints of the Stone Bed commonly trap worn sea-urchin casts and belemnites from the Chalk, mixed with beds of modern <u>Mytilus</u> <u>edulis</u> and some striking red and orange coloured <u>Nucellas</u> and <u>Littorinas</u>.

CONTENTS   Page

The Geological Society of Norfolk exists to promote
the study and knowledge of geology, particularly in East
Anglia, and holds monthly meetings throughout the year.

Visitors are welcome to attend the meetings and may
apply for election to the society. For further details
write to the Secretary, Castle Museum, NORWICH, NOR 65B.

Copies of this Bulletin may be obtained 60p (post
free) from the Society at the Castle Museum, NORWICH,
NOR 65B; it is issued free to members.

Also available at 75p (post free) is "The Geology
of Norfolk", a 108 page book describing the geology of
the county, reprinted by the Society in 1970; members
of the Society may buy one copy only at 40p.

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BULLETIN OF THE GEOLOGICAL SOCIETY OF NORFOLK

No. 22

CONTENTS INCLUDE:

EDITORIAL

    Included in this issue are the previously promised
articles on molluscs and pollen from Aldeby, and mammals
of the last interglacial in Norfolk. Continuing our
series on Geology in education, Mr. Coleman of Gresham's
School, Holt, gives his view on the subject in public
schools, and the editor contributes a review of currently
available textbooks. It is hoped to publish an article
on Geology in the Open University in the next issue.

    Bulletin No. 23 will be issued in April 1973.
Contributions should be sent to me as soon as possible,
and no later than January 31, 1973.

    Will contributors please note that manuscripts are
acceptable in legible handwriting, although typewritten
copy is preferred. In either case it would be a great
help if details of capitalisation, underlining, punctuation,
etc., in the headings and references (particularly), could
conform strictly to those used in the Bulletin.
Illustrations intended for reproduction without redrawing
should be executed in fine, dense, black ink line. Thick
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acceptable, as these tend to spread in the printing
process employed. Original illustrations should, before
reproduction, fit into an area of 225 mm by 175 mm; full
use should be made of the second (horizontal) dimension,
which corresponds to the width of print on the page, but
the first (vertical) dimension is an upper limit only.
Can all measurements be in metric units, please.

                                                  R.S.J.

MAMMALS OF THE LAST INTERGLACIAL IN NORFOLK

B. McWILLIAMS*

Mammalian remains have been found from six sites in
Norfolk thought to be of Ipswichian age - Mundesley,
Wretton, Beetley, Wortwell, Shropham and Swanton Morley.
West (1961) noted the correlation of this period and the
Morston raised beach, the likelihood of the Mundesley
'river bed' being Ipswichian, and the discovery of the
Wretton site. In the last decade four more sites have
been discovered with mammalian remains which are now in
Norwich Castle Museum. (The location of the Norfolk
sites is shown in Fig. 1.)

1. Morston

Between Morston and Stiffkey at the edge of the
marshes is what Solomon (1932) describes as a raised beach,
the top at about 7 metres above O.D.

Exposures on both sides of the River Stiffkey show
about 1 metre of beach, overlain by 1 metre of weathered
Hunstanton till on which Mesolithic flint tools have been
found. More recently (Baden-Powell and West 1960), there
has been a suggestion that the site may represent a small
glacial marginal drainage feature. However it resembles
a beach deposit more closely except that the pebble
orientation has been changed towards the vertical by
cryoturbation.

No fossils have been recorded from the beach, perhaps
not unexpectedly in such a high energy environment, and
it is presumed to be Ipswichian on stratigraphical grounds
alone.

2. Mundesley

Cut into the drift and exposed in the cliff for many
years, though now obscured by a sea wall, is the Mundesley
'river bed' described by Reid (1882) as a "thick lenticular

* Castle Museum, NORWICH

2

LAST INTERGLACIAL SITES IN NORFOLK
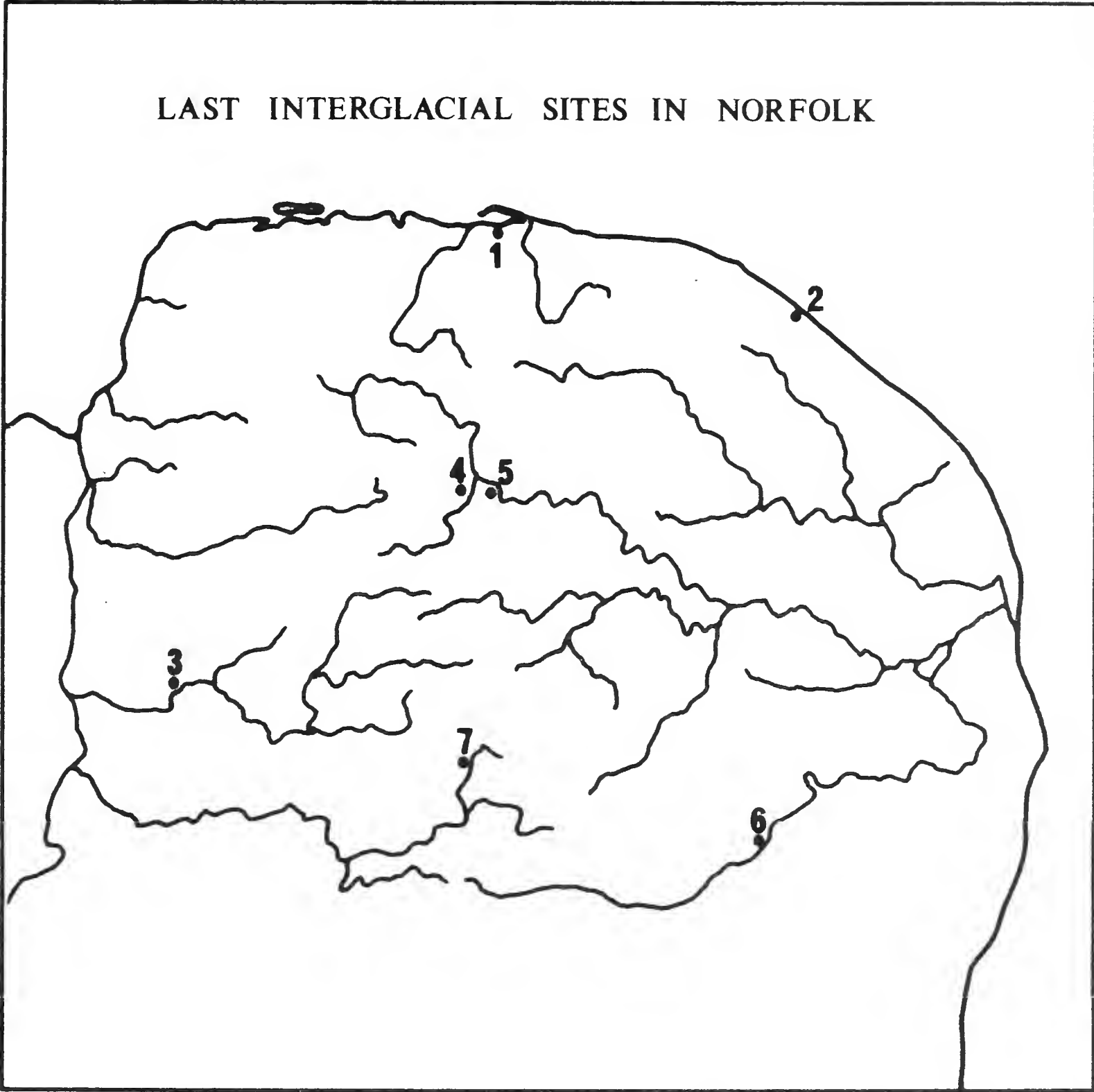
KEY

1	Morston	5	Swanton Morley
2	Mundesley	6	Wortwell
3	Wretton	7	Shropham
4	Beetley		

Fig. 1. Last Interglacial sites in Norfolk

mass of peaty loam with plant remains, shells, bones and
elytra of beetles". Following the sinking of boreholes by
the Cambridge Sub-Department of Quaternary Research in
1970, pollen studies (Miss L. Phillips, personal
communication) have proved it to be Ipswichian. The
vertebrate fauna includes Palaeoloxodon (Elephas)
antiquus and Emys lutaria, the European pond tortoise, both
in Norwich Museum.

3. Wretton

The 1961 excavations for the Fen flood relief channel
exposed Ipswichian deposits at Wretton. Apparently few
bones were found from the interglacial here, but the
stratigraphy, palaeobotany and non-marine mollusca were
studied in detail (Sparks and West 1970). Later deposits
are to be the subject of a forthcoming publication and
include vertebrate remains (West, Sparks and Joysey 1972).

4. Beetley

Near East Dereham in 1964 gravel workings exposed
organic deposits rich in mammalian remains which are now in
Norwich Castle Museum (accession no. 383.964) and were
described by Markham (1966, 1967). They include the
following: Hippopotamus amphibius L., Palaeoloxodon
antiquus (Falc. and Caut.) Cervus elaphus L., Megaceros
giganteus (Blum.) and a species of bison and rhinoceros.
Although prominent, the hippopotamus bones belong to a
single individual only. Palaeobotanical studies (Miss L.
Phillips, pers. comm.) place the hippopotamus in
Ipswichian zone f (IIb) (West 1968), the mixed oak forest
zone with high tree pollen and no evidence of much open
ground.

5. Swanton Morley

In November 1969 a gravel pit at Swanton Morley
yielded organic beds rich in plant remains, molluscs and
bones. Sediment samples from bones of Hippopotamus
amphibius L., Bos primigenius Boj. and a molar of

Palaeoloxodon antiquus (Falc. and Caut.) were analysed
for pollen at Cambridge Sub-Department of Quaternary
Research. Hippopotamus and Bos belonged to Ipswichian
zone g (III), the hornbeam zone, whilst the elephant was
assigned to the later part of zone f (IIb). All eleven
samples showed evidence of open ground with a high
proportion of grasses, Plantago lanceolata (a grazing
indicator) and Compositae (Miss L. Phillips, pers. comm.).
As at Beetley, hippopotamus is represented by a number of
associated bones of one individual. The fauna also ·
includes voles (Clethrionomys and Microtus), mouse
(Apodemus) and a single tooth of fallow deer, Dama dama (L.)
(A.J.Stuart, pers. comm.)

6. Wortwell

In 1967 workmen digging a sewer trench at Wortwell
Low Road uncovered part of the skeleton of a Straight-
tusked Elephant, Palaeoloxodon antiquus (Falc. and Caut.).
This site was the subject of a paper by Sparks and West
(1968) who showed the presence of earliest Ipswichian,
zone c (Ia), zone f (IIb) and the absence of zone g (III).
The elephant remains were later sampled for pollen by
C. Turner (1970, pers. comm.) to locate them in the
published sequence of samples, indicating an environment
of standing or slowly moving water some half to three or
four metres deep in open conditions. A pit some 35 metres
away, in the adjacent gravel terrace, has yielded mammoth,
rhinoceros, reindeer, horse and bison (in Norwich Castle
Museum) of presumed Gipping age.

The elephant remains comprise one incomplete and three
complete molars, parts of the skull, jaw and tusks, and
right fore-foot spread over an area of a six metres square
at a depth of 4.5m. More extensive excavation was
impossible as the site was below the highway and adjacent
to a dwelling-house.

One molar, a lower left third (Castle Museum no.

877.967(3)) shows certain abnormalities (Fig. 2). The
anterior half of the molar is displaced buccally,
beginning at the 7th lamellae out of 13 in wear. There
are similarities with a Forest Bed Series P.antiquus
molar described and figured by Wells (1969). The lingual
surface has a broad pit penetrating enamel and dentine at
about the margin of the gum. Anteriorly there is an
abraded area strongly suggestive of a 'push-facet'
produced during expulsion of the neighbouring tooth. The
buccal surface has a sharp-edged slot, again at the margin
of the gum some 70 mm long, 15 m wide and 10 mm deep. This
latter feature may represent the site of an infection, as
it is present at a third site at the gum margin of the
incomplete lower right molar. The occlusal surfaces of
all four teeth show no clear evidence of function
disturbance.

7. Shropham

    In October 1969 the Ipswichian date of deposits
previously exposed in a gravel pit at Shropham was
indicated on examination of many bone finds on the site.
No organic beds are now exposed but notes by R. R. Clarke
in Norwich Castle Museum dated 17.7.56 give the following
section, the lower part obtained by boring, with the
comment "?interglacial"

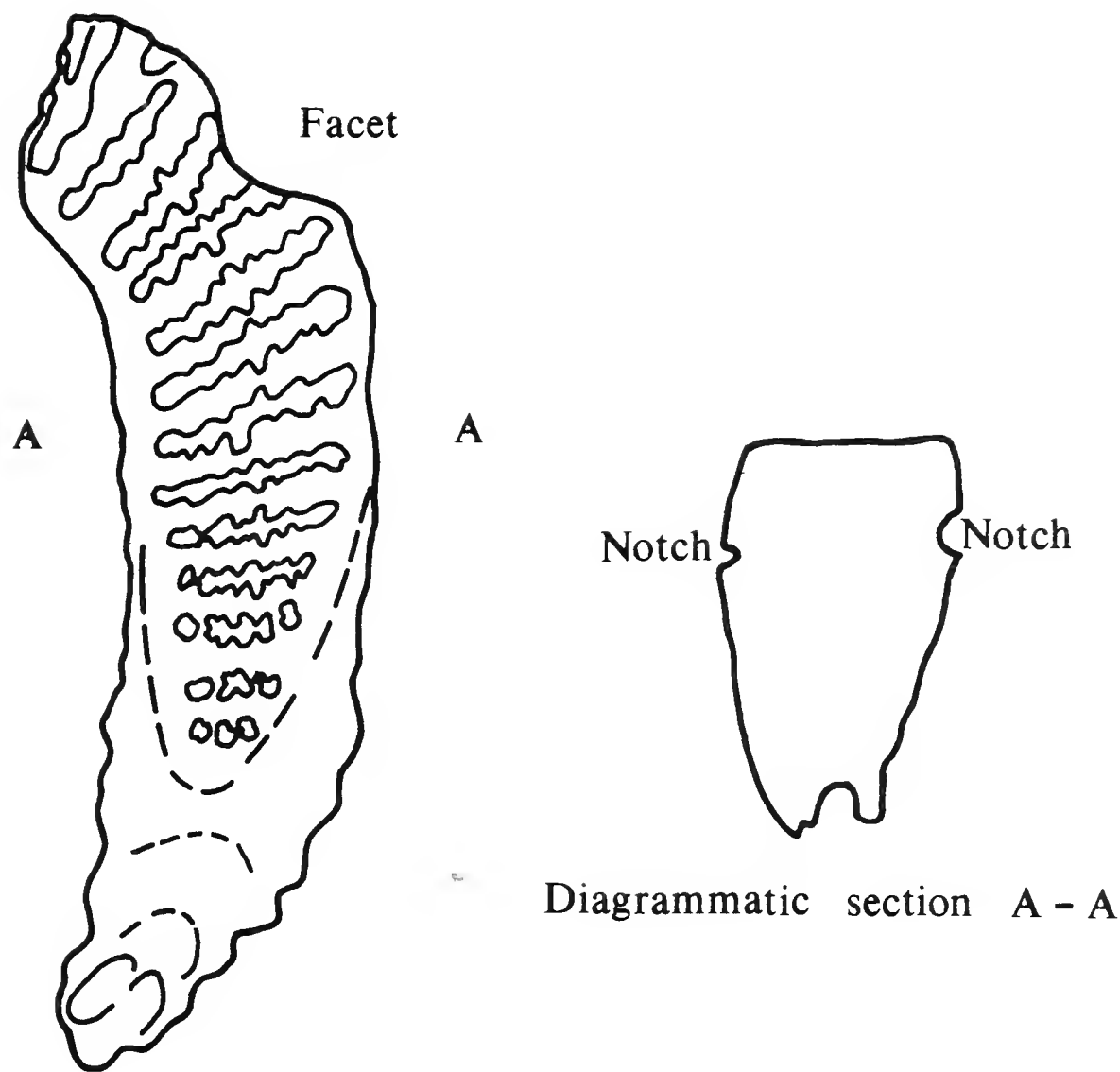| Lithology	Thickness (m)	Depth (m)
topsoil	0.3	0.3
sands	4.6	4.9
peat	1.0	5.8
gravel	6.0	11.8
peat	1.2	13
sand	1.0	14
dark mud	3.0 +	17 +

Surface at 24 m O.D.

Fig. 2.   Occlusal view of P. antiquus tooth from
          Wortwell, showing abnormalities

Some bones collected at this time are in Norwich Castle
Museum (no. 239.957) and were recorded as horse, ox, red
deer, reindeer, fallow deer and rhinoceros. The record
of fallow deer and a tooth described as brown bear in the
possession of the owner were then incorrectly identified,
they are in fact reindeer and red deer respectively.
Several hundred bones were retrieved from the site and
although badly weathered in many cases, after conservation
the following species have been identified -

Palaeoloxodon antiquus (Falc. and Caut.), Hippopotamus
amphibius L., Cervus elaphus L., Bos primigenius Boj.,
Equus caballus L., Rangifer tarandus L., Mammuthus
primigenius (Blum.), Rhinoceros sp., Bison sp., Bos sp.

Because of the poor condition of the bones a
distinction between Bos and Bison metapodials, with
estimation of age and sex has been unsuccessful.

This is obviously a mixed fauna, but the presence of
hippopotamus can be taken as a good indicator of Ipswichian
deposits, at about 13m depth. Clarke's notes suggest a
Mesolithic date from the upper peat layer at 5.8m depth
and record Bos from this level. Presumably the mammoth,
reindeer, bison and horse occurred in the intervening
gravel of Weichselian age.

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LOWER PLEISTOCENE MOLLUSCAN ASSEMBLAGES AND
POLLEN FROM THE CRAG OF ALDEBY (NORFOLK) AND
EASTON BAVENTS (SUFFOLK)

P. E. P. NORTON* and R. B. BECK**

Summary

Molluscan assemblages from the Crag at Aldeby and
Easton Bavents are described and a pollen diagram from
Aldeby is presented. This shows a Baventian pollen
spectrum enabling correlation with the deposits at Ludham
and Easton Bavents to be made. It is suggested that the
Aldeby shelly Crag is Antian in age. Palaeoecological
interpretations from the three sites are compared. The
following marine facies in the Antian - early Baventian
are deduced:

1. A littoral facies of the early Antian, with deposits
   at Easton Bavents.

2. An inner-sublittoral facies of the Antian at Aldeby,
   Easton Bavents and Ludham. The sea-bed at Aldeby
   was varied with many habitats for Mollusca. Around
   Easton Bavents it was more uniform, coarse with
   muddy interstitial material. At Ludham it was varied,
   with freshwater influence.

3. An early Baventian marine phase when the water was
   apparently deeper, and at Easton Bavents warmer as
   well, than in the Antian. The vegetational evidence
   from intercalated pollen analyses, however, suggests
   the climate was becoming colder. This problem awaits
   solution.

Introduction

Modern studies of the early Pleistocene sequence in
East Anglia are summarised by West (1968, pp. 241-246).

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**North Yarde, Bishop's Nympton, SOUTH MOLTON, N. Devon.

He recognises Stages named Ludhamian, Thurnian, Antian,
Baventian, Pastonian, Beestonian and Cromerian. Mollusca
have been described by Norton (1967) from the first four
named Stages at Ludham (below surface) and from the
Baventian at Sidestrand (outcropping). A summary of the
sequence of molluscan assemblages in all these Stages and
at many other sites is given by Norton (1970). This paper
describes the molluscan assemblages at two outcrops,
Aldeby and Easton Bavents. The shelly deposits at both
belong to the "Norwich Horizon" (Harmer 1902).

Aldeby

Aldeby Brickyard (grid reference TM 431930) was worked
during the middle 19th century. The early Pleistocene
succession is described by Rose (1868), Prestwich (1871),
Woodward (1881) and Reid (1890). Lists of Mollusca are
given by Prestwich and Woodward, from records by Crowfoot
and Dowson.

In March 1966 a section was reopened in the western
embayment of the old pit, where a large oak tree stands
below the face. The Paramoudra Club, (now the Geological
Society of Norfolk) and the Ipswich Geological Group dug
it. The succession was as follows:

0 - 60 cm	Soil
60 - 343 cm	Sands (current bedded at 148 - 162 cms) with gravelly layers at 100 - 120 cms, 130 - 148 cms and 182 - 343 cms
343 - 403 cm	Medium-fine yellow sand with brownish clay layers (no pollen) at 409 - 410 cms, 418 - 419 cms, 423 - 428 cms
441 - 503 cm	Yellow-gray silty clay (no pollen) with pockets of sand
503 - 551 cm	Grey laminated silty clay (no pollen) alternating with orange-yellow medium sand. A line of pebbles, 1 - 2 cms across, at 543 cms

551 - 638 cm   Orange loamy sand with grey laminated
                silty clay (no pollen) at 573 - 578 cms,
                silty grey clay (no pollen) at 612 - 615
                cms, layers of grey laminated silty clay
                (no pollen) at 629 - 638 cms

638 - 683 cm   Laminated silty clay alternating with
                yellow-brown silty sand. Pollen from
                660 cms downwards. At 663 cms a thin
                layer of grey-yellow weathered clay with
                a cracked surface (possible interruption
                of deposition). Below 665 cms, bluer with
                ferruginous partings

683 - 798 cm   Laminated sticky blue-grey polleniferous
                clay with partings of pure milky quartz
                sand to 786 cms; ferruginous sand partings
                below

833 - 868 cm   Fine medium-brown sand with a few shells.
                An undulating line of shells at 858 cms.
                Greyer below 843 cms

868 - 875 cm   Grey medium-fine sand densely packed with
                shells, many with the valves together

875 - 885 cm   Brown medium sand with no shells, to base of
                excavation at 885 cms.

Woodward (1881) and Reid (1890) described sections to
the east (the 'central part of the pit') and west of this
one. The 1966 profile interpolates satisfactorily. It is
suggested that the Shell Bed be considered as Antian. The
clay above is Baventian, as shown below, and no obvious
unconformity was observed in the section. The molluscan
assemblage, though less diverse, is similar to that of
Shell Beds 3 and 4 at Easton Bavents, which are demonstrably
Antian.

Pollen (R.B.B.)

Pollen samples were taken in all argillaceous layers
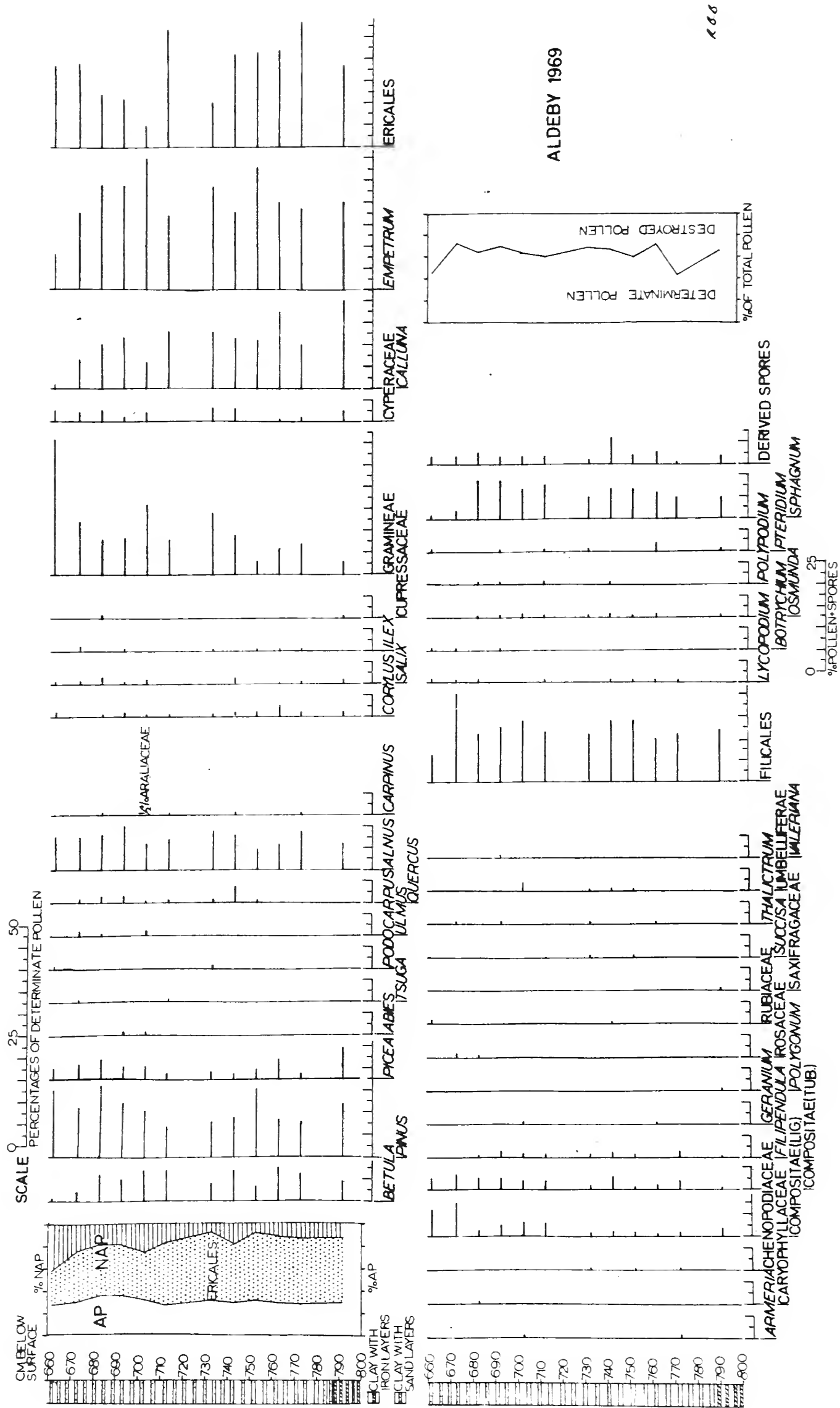but no significant pollen totals were recorded above 650 cms.

Fig. 1. Aldeby: Pollen diagram

Below this the pollen diagram shows the following features. The Arboreal Pollen (A.P.) percentage is never more than 40.   There are high percentages of Ericales pollen, from 60% at the base of the diagram to 25% at the top.   Of the trees represented, only the pollen of Betula, Pinus, Picea and Alnus reaches over 5%, the subsidiary genera being Abies, Tsuga, Podocarpus - type, Ulmus, Quercus and Carpinus.   As ready mentioned, the Ericales dominate the Non-Arboreal Pollen (N.A.P.) with subsidiary amounts of Gramineae, Cyperaceae and Compositae.   Sphagnum and Filicales are the chief non-flowering plants present throughout.

The general absence of thermophilous trees, coupled with the dominance of Ericales, suggests a correlation with one of the cold phases of the early Pleistocene proposed by West (1961) from the diagram of the Royal Society Borehole at Ludham, Norfolk.   The two cold phases there are the Thurnian, L2 and the Baventian, L4.   It is proposed that the Aldeby clay be correlated with the Baventian, subzone L4b, since Betula, Pinus and Alnus are more or less equally frequent and the rest of the diagram compares very closely with that from Ludham and also from Easton Bavents (Funnell and West, 1962).

Mollusca (P.E.P.N.)

The shells were examined using the methods described by Norton (1967). The results are shown in Table 1.

Listing the species so as to bring together those which are extinct since the early Pleistocene, or not extinct and having a similar present-day habitat, we obtain Figure 2.

The molluscan assemblages are characterised by Cyprina islandica, Spisula elliptica, Donax vittatus, Lepton nitidum, Mysella bidentata, Hiatella arctica and Cochlodesma praetenue.   During deposition there has been much abrasion of the shells.   Eighty per cent of them at 868 - 875 cms, 57% at 858 - 868 cms and 69% at 833 - 858

Table 1. Aldeby Mollusca

(Figures are to nearest 1%. 0 = less than ½%.

f = fragments only.

Dash denotes absence.)

		A 868 cms to 875 cms	B 858 cms to 868 cms	C 833 cms to 858 cms
1	Gastropods (indet.)	2	1	0
2	Gibbula sp.	0	-	-
3	Littorina littorea	0	-	-
4	L. cf. saxatilis	0	-	-
5	Clathrus clathratulus minutus	-	f	f
6	Calyptraea chinensis	0	0	-
7	Natica sp.	3	0	5
8	Nucella sp.	-	0	-
9	N. lapillus cf. lapillus	f	-	-
10	N. lapillus cf. vulgaris	-	-	0
11	N. cf tetragona	-	0	-
12	Lora trevelyana	-	-	f
13	L. cf. trevelyana	0	-	-
14	Retusa sp.	-	0	-
15	Actaeon sp.	-	f	0
16	cf. Actaeon	-	0	-
17	Pyramidellid sp.	-	0	-
18	Chrysallida indistincta	-	0	-
19	Bivalves (indet.)	12	12	10
20	Nucula sp.	0	0	0
21	N. cobboldiae	f	-	f
22	Yoldia sp.	1	3	2
23	Y. myalis	-	-	0
24	Y. cf. semistriata	0	-	-
25	Modiolus sp.	2	-	-
26	cf. Modiolus	-	6	-
27	Mytilus edulis	0	-	1
28	Pinna rudis	-	f	-
29	Anomia sp.	f	-	0
30	Astarte sp.	-	0	-
31	A. cf. incerta	-	0	-
32	A. cf. montagui	0	-	0
33	cf. Cyprina	1	-	-
34	Cyprina sp.	-	10	
35	C. islandica	7	1	
36	Lucinoma borealis	0	0	0
37	L. cf. borealis	-	f	-
38	Lepton nitidum	6	-	-
39	L. cf. nitidum	-	-	5

Table 1 continued

		A 868 cms to 875 cms	B 858 cms to 868 cms	C 833 cms to 858 cms
40	Mysella bidentata	1	2	-
41	M. cf. bidentata	-	-	1
42	M. ferruginosa	-	1	-
43	Lasaea intermedia	-	9	-
44	Cardium sp.	O	f	-
45	C. edule	f	-	f
46	Parvidardium scabrum	-	1	O
47	P. cf. scabrum	O	-	.-
48	Serripes groenlandicus	O	-	-
49	Spisula sp.	35	21	45
50	S. elliptica	1	-	2
51	S. cf. elliptica	-	12	-
52	Abra sp.	O	O	1
53	Donax sp.	2	-	-
54	D. vittatus	O	4	3
55	Macoma sp.	4	1	3
56	M. calcarea	O	-	-
57	M. obliqua	4	O	O
58	cf. Hiatella	1	-	-
59	Hiatella sp.	-	-	1
60	H. arctica	1	11	3
61	Sphenia binghami	-	O	-
62	Corbula gibba	O	O	1
63	Mya sp.	14	O	1
64	M. arenaria	O	-:	-
65	M. cf. truncata	-	-	1
66	Cochlodesma praetenue	1	2	1

———

cms are too worn for accurate determination. Presumably
this was caused by rough seas or reworking of the shells.
Turning to those which can be determined accurately, we
find a small percentage belong to species which have become
extinct since the Aldeby deposition time (1% at 868 - 875
cms - called hereafter sample A; 10% at 858 - 868 cms -
sample B; 1% at 833 - 858 cms - sample C). There is
modern ecological data on the remainder. Species of
infralittoral and littoral affinity are very poorly

ALDEBY BRICKYARD, 1966. MOLLUSCA : ECOLOGICAL GROUPS. Frequencies are to nearest 1%. 0 = less than ½%. F = fragments only.				SAMPLES, with depth below surface		
				A 868 cm to 875 cm	B 858 cm to 868 cm	C 833 cm to 858 cm
LITTORAL	INFAUNA		Cardium edule (45)	F		F
LITTORAL	EPIFAUNA		Littorina cf saxatilis (4) L. littorea (3) Nucella lapillus (9) Mytilus edulis (27)	0		1
INFRA-LITTORAL	IN-FAUNA		Mya arenaria (64)	0		
INFRA-LITTORAL	IN-FAUNA		Cochlodesma praetenue (66)	1	2	2
INFRA-LITTORAL	EPIFAUNA		Calyptraea chinensis (6)	0	0	
SUBLITTORAL	INFAUNA	WIDE TOLERANCE	Parvicardium scabrum (46)	0	1	0
SUBLITTORAL	INFAUNA	COARSE MATERIAL WITH MUD	Spisula cf elliptica (50,51) Macoma calcarea (56) Corbula gibba (62)	1	13	3
SUBLITTORAL	INFAUNA	CLEAN FINE OR SANDY OR MUDDY COARSE	Astarte montagui (32)	0		0
SUBLITTORAL	INFAUNA	MUDDY FINE OR COARSE	Lucinoma borealis (36)	0	0	0
SUBLITTORAL	INFAUNA	FIRM SAND OR MUDDY SAND	Cyprina islandica (35)	7	1	10
SUBLITTORAL	INFAUNA	SAND, SANDY MUD OR CLAY	Mya cf truncata (65)			1
SUBLITTORAL	INFAUNA	CLAY, ARCTIC DISTRIBUTION	Serripes groenlandicus (48)	0		
SUBLITTORAL	INFAUNA	CLEAN FIRM SAND	Donax vittatus (54)	0	4	3
SUBLITTORAL	EPIFAUNA	STONES OR SHELLS	Hiatella arctica (60) Sphenia binghami (61)	1	11	3
SUBLITTORAL	EPIFAUNA	SHELLY MUD AND FINE SAND	Chrysallida indistincta (18)		0	
SUBLITTORAL	EPIFAUNA	MUDDY SAND OR CLAY	Lora trevelyana (12,13)	0		F
SUBLITTORAL	EPIFAUNA	COMMENSAL — HOST IN MUDDY SAND OR SHELLY GRAVEL	Lepton nitidum (38,39) Mysella bidentata (40,41)	7	2	6
SUBLITTORAL	EPIFAUNA	COMMENSAL — HOST IN CLEAN, COARSE MAT'L	Montacuta ferruginosa (42)		1	
SUMMARIES	Numerals after species & here refer to Table 1	5, 10, 11, 21, 23, 24, 28, 31, 43, 57.	EXTINCT	1	10	1
SUMMARIES		1, 2, 7, 8, 14, 16, 17, 19, 20, 22, 25, 26, 29, 30, 33, 34, 44, 49, 52, 53, 55, 58, 59, 63.	ABRADED	80	57	69
SUMMARIES		INFORMATIVES	TOTAL INFORMATIVE	19	33	30
SUMMARIES			LITTORAL & INFRALITTORAL	2	2	4
SUMMARIES			SUBTIDAL EPIFAUNA	8	14	9
SUMMARIES			SUBTIDAL INFAUNA	9	17	17

Fig. 2. Aldeby: Mollusca, showing ecological groups

represented (2% - 4%). Sublittoral forms are prevalent
(sample A, 17% in the 19% of fully determinable shells;
sample B, 31% in 33%; sample C, 17% in 26%). Three
types are particularly frequent. Spisula elliptica,
Corbula gibba and Macoma calcarea are the most frequent
and at the present day are found in coarse bottom material
with interstitial mud. Cyprina islandica, the next,
inhabits firm or muddy sand. Donax vittatus, the other,
lives in clean firm sand. It is much less frequent in
the samples. In very small numbers occur types which
today are associated with shell gravel on the one hand
(Parvicardium scabrum) and with clay or mud on the other
(Serripes groenlandicus, Mya truncata).

Turning to what is interpreted as the sublittoral
epifaunal element of the death assemblages, one of the
most frequent species is Hiatella arctica (1% in 8%,
sample A; 11% in 14%, B; 3% in 9%, C). H. arctica inhabits
crevices and laminarian holdfasts, etc. on a clean stony
or shelly bottom. Two other frequent epifaunal forms are
Lepton nitidum and Mysella bidentata which are commensals.
Their hosts live in muddy and sandy gravel.

On the basis of modern habitat preferences therefore,
the life-associations from which these degraded death-
assemblages came are interpreted as having lived in shallow
sublittoral conditions in a sandy-bottomed sea with mud and
some coarser material in patches. The evidence is that a
variety of habitats were found in the area, from which the
various infaunal and epifaunal types (already mentioned)
were derived. A depth of 10 - 15 m below mean low tide
mark or not more than 20 m is suggested as that at which
they lived and were deposited. All the characterising
species would flourish in this range. If the sea had been
deeper at the place of deposition the assemblages would
have been less abraded and if it had been shallower there
would have been more littoral forms.

However, mechanical analyses (Table 2) show that the
Aldeby sediments are very well sorted.

Table 2 Mechanical analyses of the Aldeby Shell Bed

	% by weight in Sample		
	A	B	C
	868-875 cms	858-868 cms	833-858 cms
Fine gravel to 2000 μ	6.3	0.7	0.3
Coarse sand to 600 μ	5.9	1.7	1.2
Medium sand to 210 μ	32.1	33.9	44.8
Fine sand to 60 μ	44.8	58.2	54.2
less than 60 μ	10.9	5.0	0.4

Mr. P. G. Cambridge made these analyses. Subsamples of
about 100 gms were obtained using a sample splitter. They
were shaken for 10 minutes on an Endecott machine using
sieves with BSS meshes 8, 14, 16, 25, 36, 72, 120, 200.

Except in Sample A the principal component is in the
medium and fine sand grades, with little coarse material
or fines. It is supposed that the whole shell bed has been
formed as a concentrate by turbulence or migration of
channels on the sea-bed, but that the part from 868 - 875
cms (sample A) approaches more closely the original
conditions of the life-environment. Shells were found
here with the valves together.

Most of the species are typical of the Boreal
zoogeographic region at present. Serripes groenlandicus
(one valve in sample A) is now an Arctic form. Macoma
calcarea (one individual in sample A) is now only relict
in the Boreal region. In the same sample is Calyptraea
chinensis, now a Lusitanic form. This 'overlapping' has
been noted in the Ludham Borehole assemblages also, at all
levels (Norton 1967).

Easton Bavents

The succession is described, with a summary of
literature and a description of the vegetational and

foraminiferal· sequence, by Funnell and West (1962). They
also summarise previous work on the Mollusca, especially
by Larwood and Martin (1953) and on heavy minerals
(Solomon 1935 and appendix to Funnell and West op cit.).

A series of samples was taken by Norton and Dr. R. G.
West in 1967. The lithology was not precisely the same as
described in 1962, the cliff having gone back several
metres.

above 0 cm Blue-grey laminated clay (Baventian clay)
(= 4.42 m O.D., levelled)

0 -	30	cm	Rusty clay with sand partings
30 -	45	cm	Stony sand
45 -	78	cm	Shell Bed 1 (sampled)
78 -	124	cm	Red loamy sand, fewer shells
124 -	138	cm	Shell Bed 2, more comminuted (sampled)
138 -	162	cm	Red loamy sand and shells
162 -	175	cm	Shell Bed 3 (sampled)
175 -	230	cm	Red loamy sand and shells
230 -	247	cm	Shell Bed 4 (sampled) ·
247 -	265	cm	Pale sand, grey clay laminae at 260 cms and (thinner) below
265 -	270	cm	Redder sand
270 -	271	cm	Red-grey clay lamina
271 -	280	cm	Shell Bed 5 (sampled)
280 -	290	cm	Red-grey sand laminated with grey clay at 289 cms.

The following correlations are proposed on comparing
this section (seen 1967) and Funnell and West's section
(seen 1961).

0 cms (1967 section) = 175 cms (1961 section)
Shell Beds 1 and 2 (1967) are Baventian.
(L4b pollen was at 175 - 210 cms (1961), above the level of
Shell Bed 1 (1967). Zone E.B. II Foraminifera were at
265 cms (1961), below the level of Shell Bed 1 (1967) and

at 300 cms (1961), at the level of Shell Bed 2 (1967).
L4b pollen was also at 300 cms.)

Shell Beds 3, 4 and 5 (1967) are Antian.
(They fall between the boundaries of Pollen Zone L3 on
West's diagram from the 1961 section, though the actual
Antian pollen occurred only at 388 - 390 cms then - below
the level of Shell Bed 3 (1967) but above 4 and 5.)

Mollusca (P.E.P.N.)

The Mollusca which occurred in the Shell Bed samples
are given in Table 3 and arranged for interpretation
purposes in Figure 3.

Table 3. Easton Bavents 'B' Mollusca
(Frequencies are to nearest 1%. 0 = less than $\frac{1}{2}$%

f = fragments only

Dash denotes absence.)

Shell Bed

	1	2	3	4	5
			Depth		
	45 cm to 78 cm	124 cm to 138 cm	162 cm to 175 cm	230 cm to 247 cm	271 cm to 280 cm
1 Chiton plates	-	f	-	-	-
2 Gastropod (indet.)	3	3	1	6	8
3 Gibbula sp.	1	0	-	-	-
4 Littorina sp.	4	5	-	-	-
5 L. littorea	-	-	-	2	7
6 L. saxatilis	2	3	1	-	12
7 Clathrus sp.	-	f	-	-	-
8 Calyptraea chinensis	0	2	3	-	-
9 Natica sp.	-	-	1	-	-
10 Nucella lapillus	1	f	2	-	f
11 Buccinum undatum	-	-	-	f	-
12 Retusa sp.	0	-	-	-	3
13 Bivalve (indet.)	5	8	9	1	6
14 Nucula sp.	f	-	2	-	-
15 N. cobboldiae	-	0	0	-	-
16 Yoldia sp.	2	3	5	7	0
17 Y. cf. myalis	-	-	1	1	-
18 Mytilus sp.	1	-	1	-	1
19 M. edulis	-	1	-	1	2
20 Chlamys opercularis	-	-	-	f	-

Table 3 continued   Shell Bed

	1	2	3	4	5
			Depth		
	45 cm	124 cm	162 cm	230 cm	271 cm
	to	to	to	to	to
	78 cm	138 cm	175 cm	247 cm	280 cm
21 C. tigerinus	O	-	-	-	-
22 Anomia sp.	-	O	-	f	-
23 Astarte sp.	7	-	-	-	-
24 A. montagui	-	2	-	-	-
25 A. cf. montagui	-	2	1	-	-
26 A. cf. montagui or incerta	-	1	-	-	-
27 Cyprina islandica	O	1	2	2	-
28 Diplodonta or Lucinoma sp.	-	-	-	1	O
29 Leptonid	-	1	-	-	5
30 Lepton cf. deltoideum	-	-	-	-	O
31 Mysella sp.	-	-	-	-	1
32 Cardium sp.	5	4	1	4	15
33 C. edule	-	O	-	1	2
34 C. cf. edule	-	-	-	-	5
35 Veneracean	-	O	-	-	-
36 Venus sp.	-	-	-	1	-
37 V. ovata	O	1	O	-	O
38 Venerupis sp.	O	-	-	-	O
39 Spisula sp.	7	11	-	3	9
40 S. cf. elliptica	-	O	-	-	-
41 S. cf. subtruncata	-	-	2	-	1
42 Abra sp.	O	1	-	-	2
43 Scrobicularia cf. plana	-	-	1	-	-
44 Tellinid	-	-	-	4	15
45 Macoma sp.	10	4	24	18	-
46 M. calcarea	O	-	12	10	-
47 M. obliqua	1	1	18	23	1
48 M. praetenuis	-	-	-	5	-
49 M. cf. praetenuis	-	-	1	-	-
50 Hiatella arctica	-	2	-	-	-
51 Corbula gibba	47	40	11	4	1
52 Sphenia binghami	-	O	-	-	-
53 Mya sp.	1	2	O	4	-
54 M. arenaria	2	1	-	-	-
55 Cochlodesma praetenue	1	-	O	-	-

In Shell Bed 1, 44% of shells were not possible to determine accurately; in Shell Bed 2, 44%; Shell Bed 3, 43%; Shell Bed 4, 53%; Shell Bed 5, 68%. On the basis of the remaining shells, which could be accurately determined, the following paleoecological interpretation is offered. The sequence is considered in three parts.

Shell Bed 5, 271 - 280 cms

Characterising species are Littorina saxatilis, L. littorea, Cardium edule, Mytilus edulis, Corbula gibba. Intertidal forms are the commonest, sublittoral ones are almost absent. Littorina saxatilis occurs on rocky surfaces and cannot be in situ here. Shell Bed 5 is interpreted as a littoral or infralittoral deposit. If more shells had been determinable, a larger sublittoral component might have been counted, for instance the 9% of Spisula sp., 5% of Leptonidae and 2% of Abra. Note however there are also 15% of Cardium sp, 8% Gastropoda and 15% Tellinidae, about which no such suggestion is valid. Zoogeographically the characteristic species are at present Boreal forms, common in northwest European waters.

Shell Beds 3 and 4, and associated deposits, 162 - 247 cms

Characterised by Macoma obliqua, M. calcarea, Corbula gibba, Cyprina islandica, Spisula subtruncata and Littorina littorea. Here, sublittoral forms outnumber littoral ones by 3 or 4 to 1. This is a contrast with Shell Bed 5 (discussed below). Among the sublittoral forms the only frequent ones are infaunal types, Corbula gibba and Macoma calcarea. These live in coarse bottom material with interstitial mud. This is not the type of deposit in which the remains occurred.

EASTON BAVENTS 'B', 1967 MOLLUSCA : ECOLOGICAL GROUPS Frequencies are given to nearest 1%. 0 = less than ½%.　F = fragments only .	SHELL BEDS, with depth below Baventian Clay base .				
	1 45 to 78 cm	2 124 to 138 cm	3 162 to 175 cm	4 230cm to 247 cm	5 271 cm to 280 cm
TIDAL ZONE — **INFAUNA** — Cardium edule(33, 34) Scrobicularia cf plana (43)		0	1	1	7
TIDAL ZONE — **EPIFAUNA** — Littorina saxatilis (6) Littorina littorea(5) Nucella lapillus (10) Mytilus edulis (19)	3	4	3	3	21
INFRALITTORAL — **INFAUNA** — SANDY GRAVEL, SAND OR MUD — Mya arenaria (54)	2	1			
INFRALITTORAL — **INFAUNA** — SAND OR MUDDY GRAVEL — Cochlodesma praetenue (55)	1		0		
INFRALITTORAL — **EPIFAUNA** — ON STONES ETC: SILTY PLACES — Calyptraea chinensis (8)	0	2	3		
SUBLITTORAL — **INFAUNA** — WIDE TOLERANCE — Venus ovata (37)	0	1	0		0
SUBLITTORAL — **INFAUNA** — COARSE MATERIAL WITH MUD — Spisula cf elliptica (40) Macoma calcarea (46) Corbula gibba (51)	48	40	23	15	1
SUBLITTORAL — **INFAUNA** — CLEAN FINE OR SANDY OR MUDDY COARSE — Astarte montagui (24,25)		5	1		
SUBLITTORAL — **INFAUNA** — SAND, SILTY SAND OR MUDDY SAND — Spisula subtruncata (41)			2		1
SUBLITTORAL — **INFAUNA** — FIRM SAND OR MUDDY SAND — Cyprina islandica (27)		1	2	2	
SUBLITTORAL — **EPIFAUNA** — STONES OR SHELLS — Sphenia binghami (52) Hiatella arctica (50)		2			
SUBLITTORAL — **EPIFAUNA** — FIRM BOTTOM OF ROCK OR MUD — Buccinum undatum (11)				F	
SUBLITTORAL — **EPIFAUNA** — SHELL GRAVEL, SANDY GRAVEL, OR SANDY MUD — Chlamys opercularis (20)				F	
SUBLITTORAL — **EPIFAUNA** — STONES, GRAVEL, COARSE SANDY MUD — Chlamys tigerinus (21)	0				
SUMMARIES — Numerals after species and in this column refer to Table 3. — 15, 17, 30, 47, 48 — EXTINCT	1	1	21	28	1
SUMMARIES — 1, 2, 3, 4, 7, 9, 12, 13, 16, 18, 22, 23, 26, 28, 29, 31, 32, 35, 36, 38, 39, 42 44, 45, 53. — ABRADED	44	44	43	53	68
SUMMARIES — INFORMATIVES — TOTAL	55	55	36	19	31
SUMMARIES — INFORMATIVES — LITTORAL & INFRALITTORAL	6	6	7	4	28
SUMMARIES — INFORMATIVES — SUBLITTORAL	49	49	29	15	3

Fig. 3.　Easton Bavents 'B': Mollusca, showing
　　ecological groups

Table 4.   Mechanical analyses of the Easton
           Bavents Sediments

	Shell Bed				
	1	2	3	4	5
Fine gravel to 2000 µ	11.3	26.0	28.9	10.9	5.8
Coarse sand to 600 µ	21.5	39.3	26.1	10.6	7.8
Medium sand to 210 µ	52.8	17.7	27.9	21.8	63.4
Fine sand to 60 µ	13.9	15.3	16.8	52.1	22.3
finer than 60 µ	1.6	1.9	0.3	5.4	0.7

(These were made by Mr. P. G. Cambridge by the same methods
as were used for the Aldeby Analyses).

The mechanical analyses of the sediments (Table 4)
show that Shell Bed 4 has a preponderance of fine and medium
sand, Shell Bed 3 being well dispersed but coarser. Neither
bed contained much silt or clay. This with the lithology
of the deposit and the high percentage of abraded shells,
suggests that the death assemblages are allochthonous.

The species, as in Shell Bed 5, are mainly distributed
in Boreal waters today. _Macoma calcarea_ has a Subarctic
distribution, with relict populations in the Danish Belt
Seas. _Macoma obliqua_, now extinct, is very frequent in
these shell beds.

Shell Beds 1 and 2 and associated deposits, 45 - 138 cms

Characterising species are _Corbula gibba_, _Littorina
saxatilis_, _Astarte montagui_, _Mya arenaria_, _Hiatella arctica_.
The sublittoral forms again outnumber the littoral ones
here, by about 8 to 1. _Corbula gibba_ forms about 40% of
the assemblage. Its ecology has been described by Yonge
(1946). It is specialised for life in gravel and small
stones with thick muddy sand. Table 4 shows much coarse
material in the sediment but a lack of silt and clay.
Macoma calcarea, common in Shell Beds 3 and 4, is
insignificant here (further discussion below). It is

considered that the Mollusca generally indicate
temperatures similar to those of modern Boreal seas, and
that they are deposited in sediments other than those
in which they lived.

General Discussion. It has been noted that the Mollusca,
in life, would have inhabited sediments unlike those in
the Shell Beds. The present Shell Beds were probably
concentrated by migration of channels on the sea-bed and
by turbulent conditions. It is not easy to conclude the
depth at which they formed. The ratio of sublittoral
forms to littoral ones changes from one shell in nine
(Shell Bed 5) through 3 : 1 (Bed 4) and 4 : 1 (Bed 3) to
8 : 1 (Beds 1 and 2). Shell Bed 5 is considered to be a
littoral or infralittoral deposit, formed less than 5 m
below mean low tide mark. The infrequency of littoral
forms in the other shell beds suggest that they formed in
more than 5 m of water, while the frequency of worn shells
suggests formation in less than 15 m. It is inferred
(from the ratios above) that the water became deeper as
deposition continued, and less turbulent so that in Shell
Beds 1 and 2 markedly fewer shells are abraded (as
mentioned above). These species in the Shell Beds, which
are interpreted as sublittoral on the basis of their
modern ecology, all would flourish today between 5 m and
15 m depth.

   Macoma calcarea and Corbula gibba occur in Shell Bed
3 where they are very frequent. Corbula gibba alone
occurs in Shell Bed 2 (with a higher frequency, equal to
its own in Shell Bed 3 plus that of M. calcarea there).
It is possible that ecological changes caused this
'replacement', for example an alteration in the sea-bed
type or the water temperatures. However, both species
flourish in coarse material with interstitial mud. The
habitat of Corbula gibba has already been referred to,

that of <u>Macoma</u> <u>calcarea</u> is mud, with clay, stones, shells
and gravel (Odhner 1915). On the other hand, their
temperature tolerances are different. <u>M</u>. <u>calcarea</u>,
according to Sorgenfrei (1958, p.391) has its maximum
occurrence at an annual average of 7°C, <u>Corbula</u> <u>gibba</u>
at 10 - 15°C. This suggests the water was warmer when
the ·Shell Bed 2 molluscs were living than when those in
Shell Bed 3 were living. However, there is no corres-
ponding change in the Ludham Borehole Mollusca at the
Antian-Baventian boundary (Norton 1967). Also, the
pollen at these levels indicates increasing cold at both
sites. Thus the change in the Easton Bavents Mollusca
may be due to some alteration in the depositional
conditions, not to ecological changes.

Marine Facies in the Antian and Early Baventian

No molluscan species or group of species can be used
to infer synchroneity or non-synchroneity between the
Shell Beds at Aldeby, Easton Bavents and Ludham (Zones
L.M.5 and L.M.6). Certain resemblances emerge in the
paleoecological interpretations based on these shell
assemblages. One such resemblance (discussed below)
exists between Shell Beds 3 and 4 at Easton Bavents and
the Shell Bed at Aldeby. These Easton Bavents beds are
Antian, on palynological grounds. It has therefore been
proposed (above) that the Aldeby Shell Bed be considered
Antian, though it lacks pollen, and zone L4a is missing at
Aldeby, where the overlying clay is Baventian, L4b subzone.
If this proposal is accepted, a preliminary discussion of
distribution of marine facies during the Antian and early
Baventian can be attempted. The interpretations from the
molluscan assemblages are thought to have local, not
general, significance.

Shell Bed 5 at Easton Bavents is interpreted as part
of a local littoral marine facies of the early Antian.
The Mollusca which remain unworn enough to determine are
mainly littoral forms.

The Crag of Aldeby and the Easton Bavents Shell Beds
3 and 4 are considered to represent an inner-sublittoral
marine facies of Antian age. At Aldeby, a diversity of
habitats on the sea-bed is represented in the death
assemblages. At Easton Bavents, less diverse molluscan
assemblages occur. The commonest forms are bivalves
specialised for life in coarse sea-beds with muddy
interstitial material. At Ludham, an inner-sublittoral
facies with proximity of estuarine conditions existed
throughout the Antian (Norton 1967). Conditions there
were less turbulent. Fewer abraded shells occur. Hydrobia
ulvae is common and Planorbis leucostoma occurs.

Shell Beds 1 and 2 at Easton Bavents and Zone L.M.6
at Ludham are Baventian. There are lower percentages of
littoral forms than in the Antian assemblages. Apparently
the sea had become deeper at both sites. There is also an
indication (possibly misleading) that it became warmer at
Easton Bavents, but no such evidence at Ludham, as noted
already. Vegetational evidence, however, indicates the
climate was becoming colder and a glacio-eustatic fall of
sealevel would be expected. No explanation can be offered
for this apparent contradiction. Evidence should be sought
that the Baventian molluscan assemblages were formed by
reworking of Antian shell beds. This is not so far forth-
coming. Instead of an increase in the percentage of
abraded shells, there is a decrease at Easton Bavents. At
Ludham, there is a decrease then an increase. For a
solution of this problem, more sites must be studied.

whilst at the Sub-department of Quaternary Research, University of Cambridge. Colonel Freeland kindly sanctioned the excavation on his land at Aldeby.

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GEOLOGY AT GRESHAM'S SCHOOL

R. COLEMAN*

A feature of Technical colleges and Comprehensive schools is the wide range of courses offered at both 'O' and 'A' levels, with all sorts of rare combinations possible according to the students' choice. In smaller units, Grammar and Public schools, the range of subjects which is possible is generally more restricted, and, even after the past decade or so, in which Geology has received the "rubber stamp" of approval, it is still not widespread as an examination science or as a general curriculum subject. Gresham's School, whose foundation dates from the middle of the sixteenth century, has developed a strongly science-oriented reputation over the past seventy years - a reputation built on a large number of Oxbridge awards and places gained each year and notable distinctions of Old Boys. A traditional situation of this kind is not perhaps an ideal one into which one can make easy inroads with a "new" subject.

After a few tentative years when Geology was offered as a fourth 'A' level to the bright scientist or keen geologist, the subject for the past five years has been given the status of a normal 'A' level with a full two year course. It therefore takes its place in the four groups of subjects offered at 'A' level, each sixth-former selecting one subject from two to four of the groups according to his abilities and career needs. The boy is regarded as more important than the system - hence the wide choice of possible courses.

Boys studying Geology at Gresham's tend to fall into three major categories:

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(i)   Boys intending to read Geology at University.

(ii) Boys keenly interested who feel a high grade
      (for University entry) possible, yet who
      will be reading some other subject as
      undergraduates.

(iii) Boys whose Mathematics is not strong enough
      to cope with Physics 'A' level with great
      success, and who wish nonetheless to gain
      three science 'A' levels, combining Geology
      with, usually, Biology and Chemistry. A
      large number of these will possibly have
      careers in agriculture, veterinary science,
      information science, technical writing, soil
      science, land surveying or museum work in
      mind, and find Geology acceptable as a means
      of getting onto a science-based degree course.

It is pointed out that the ideal base of 'A' levels
for a degree course in Geology is more probably Chemistry,
Physics and Mathematics than Geology itself, but the sixth
former may be faced with the problem of entrance
competition with, possibly, lower grades in some of these
'ideal' subjects; the weaker scientist may therefore turn
to Geology. The total numbers involved generally remain
between ten and fifteen in each year.

The organisation of the sixth form Geology course is
naturally dictated by the needs of the examining boards'
syllabus, the Oxford and Cambridge Board this year revising
their requirements after a long unchanged run. The major
changes incorporate some of the newer discoveries in Geology
and attempt to cut down the amount of rote learning required,
by placing more emphasis on the understanding of geological
principles. A considerable amount of economic and
engineering geology is included, and a new approach to
the treatment of British Stratigraphy. It has long been
apparent that it is unreasonable, some have said it more

strongly, for the beginner, to expect even a moderately
detailed knowledge of the whole of British Stratigraphy
at 'A' level. It is, at the same time however, difficult
to examine the understanding of the subject of candidates
who have a less detailed knowledge. To overcome these
difficulties the new syllabus requires knowledge on two
levels: one, a general outline of British Stratigraphy
such as might be obtained from a '25 mile to the inch' map,
and, two, a detailed knowledge of three specified
stratigraphical systems which are changed annually. . This
part of the syllabus is regarded as the equivalent of
"set books" in English Literature or special subjects in
History.

Three papers are set:

Paper I consists of nine compulsory questions, each with
some internal choice, covering the general principles
of all major parts of the syllabus. This paper thus
examines the candidate's general overall grasp of
the subject.

Paper II is a traditional essay paper requiring a greater
depth of knowledge with a question on the candidate's
own fieldwork.

The third paper is a three hour practical with emphasis
placed on the candidate's understanding of the
geological significance of specimens rather than an
ability to simply name, date and classify them. The
interpretation of geological maps and photographs
illustrating geological phenomena is included.

Two important lines of thought are used to develop
this syllabus into a course. Firstly the subject should
if possible proceed from the easy to the difficult over
two years, and, secondly, those aspects of the subject
which are observable and familiar today should precede
those which are less familiar and perhaps completely
theoretical. Nearly all sixth form Geologists will have
recently completed an 'O' level Geography course and find

that the erosion processes leading on to sedimentation a
field of study in which sixth form work habits can
comfortably be acquired. Much later the more difficult
topics of igneous and metamorphic petrology, and earth
structures, with the complex theories that accompany them,
can be more readily assimilated by the attuned mind than
by the raw, recently graduated fifth former still
accustomed, however regrettably, to the rote of 'O' level
learning.

The course depends heavily for its stimulation on very
good collections of minerals, rocks and fossils, which are
available and with which the sixth former becomes familiar
over two years. Individual sets are being prepared for
each member of the course, though these may not have the
uniformity one would wish to see, notably among the fossils,
and replicas are prepared where required.

From the outset emphasis is placed on the essential
fact that Geology is very much a fieldwork subject, and
the true laboratory is the quarry or cliff-face. Our own
courses are organised so that each candidate will have
visited three quite different areas before examination.
These areas - Northern Ireland, North Wales, Shropshire,
the Lake District, Dorset and Western Scotland - offer a
coverage of the major stratigraphical groups and the work
given to the boys depends on their interests and attain-
ments. It is hoped to achieve a recapitulation of material
covered in the course to date, and to encourage original
observations and the recording of evidence prior to further
deduction. As a further incentive to members of the course,
the building up of private collections is encouraged, and
the success of this suggests that a number of family
holidays have perhaps been turned into minor expeditions.

In addition to the main field courses, we are able
to timetable the first year sixth form for a long session
of geology in the summer term, enabling whole or half day
visits to be made to some major East Anglian sites -

Hunstanton, nearby Weybourne, Wells and Trimingham, and beyond to the Charnwood Forest area and Corby.

Geology is not included in the curriculum prior to the sixth form, but a two hours' Hobbies session is organised for boys in the middle school who have an interest in the subject. This varies in form, including short field trips, fossil replica making, rock cutting and polishing, and films, the purpose being to encourage as many "geologists" as possible and give younger boys some indication of the spirit and purpose of the subject.

It does not seem likely that the subject will have opportunity for much expansion as an academic discipline at this level since most University seeking candidates for undergraduate Geology are not over keen that they should have Geology among their 'A' levels. Understandably, with techniques in the Earth Sciences becoming increasingly sophisticated and complex, it is more than ever necessary for candidates entering honours courses to have a thorough grounding in basic sciences like mathematics, physics and chemistry. The problem facing this schoolmaster is that of discouraging the would be professional geologist from his present geological studies and at the same time hoping to sustain his interest whilst two years of other scientific 'A' levels occupy his time and energies. If the subject is really one which many of the Universities would prefer to teach from the beginning its future in schools is bleak. This writer believes, however, that in many respects it has a considerable educational value and discipline which may outweigh the worth of several other sciences. Thirty-five years ago, A. E. Trueman wrote:

"Geology is pre-eminently the layman's science. In it more than in any other science there is opportunity for a beginner to make original observations, to weigh up evidence, to co-ordinate his facts, and in general to acquire a truly scientific outlook, whereas a layman can do no more in many sciences than accept ready made

conclusions, often explained by clever but dangerous
analogies, without any prospect of understanding the steps
by which they have been reached". And later, "the
geologist acquires an eye for country and an understanding
of nature not excelled by that of the artist or the poet".

Much has changed in Geology since 1937, but I believe
Trueman's thesis remains sound, and, with a growing
appreciation of his environment by the well educated man,
and an increasing encouragement from further and higher
educational circles, Geology will continue to expand at
school level.

BOOKS FOR STUDYING G.C.E. AND C.S.E. GEOLOGY

R. S. JOBY*

With the growing popularity of this subject as a
school examination subject at all levels, there has been
an increased demand and production of books suitable for
those studying in schools and colleges. When starting new
courses, teachers are faced with over one hundred possible
titles, so in this article it is intended to examine some
of those used with success by pupils and teachers, as a
guide to those venturing into the field of Geology teaching.

All G.C.E. boards offer 'O' or 'AO' level papers, and
all except Southern board offer 'A' level papers. Only a
few C.S.E. boards have Mode 1 Geology examinations at
present, but this should not deter potential teachers of
the subject, as they can compose their own Mode 3 syllabus,
which can be a very satisfying experience to those who find
existing syllabuses frustrating.

With more than 1,000 schools teaching the subject, and
more starting annually, there is a wide market for
examination-oriented Geology books, and many of a different
nature find their way into school libraries.

Few syllabuses have appended booklists., but by studying
the syllabuses and publishers' lists, as well as the books
themselves, one can work out the books available in print
for the sections of the intended course. No single text
comes anywhere near to covering any single syllabus
adequately. The Cambridge 'AO' mapwork has been metricated,
and no suitable introductory book in English appears to be
available.

For C.S.E. and 'O' level syllabuses, the book giving
the fullest coverage without loss of accuracy is 'A New
Geology' by Michael Bradshaw, published by English
Universities Press in 1968 and reprinted since. The

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diagrams are simple and easy to understand, and many of
the photographs have not been used before in similar
publications. Given that most pupils are new to the
subject, and that the vocabulary will be unfamiliar to
them, Bradshaw uses heavy type for every new technical
term, which is then explained. There is no separate
glossary, but judicious use of the index and text will
enable a pupil to reach the same end result. An important
feature is the effort to get the pupil to think three-
dimensionally, and to consider the contents of each
section with some searching tests and exercises at the
end. Necessarily in the span of 250 pages, all topics
have to be limited in their scope and number of examples,
and this is especially so of map and practical work,
covered in further volumes.

In conjunction with E. A. Jarman, Michael Bradshaw
has produced two mapwork books in paper covers. The first
deals with 1" Geological survey maps, describes and
analyses them, while the second is a disposable map
exercise book with useful step-by-step methodology. The
books can be used separately, but as previously mentioned,
are not metricated, while the Cambridge paper is. Also
available for 'O' level mapwork, and likewise in Imperial
units, is George Bennison's 'Introduction to Geological
Strata and Maps', again with exercises to be done in the
book. This is published by Edward Arnold and is now in
its second edition. On the whole this lacks many of the
qualities of the former books, and does not develop three-
dimensional awareness so well.

More specialized books are needed for specific parts
of the Geology syllabuses, and if money is in short supply,
as so often now, then for Palaeontology and Petrology, two
pocket-size handbooks published by Paul Hamlyn can be
recommended. 'Rocks and Minerals' by Zim and Shaffer covers
many more types than a general textbook, is very fully
illustrated in colour, and is useful for the young field-

worker. Its companion 'Fossils' illustrates large numbers of the major fossil phyla, but is weak in their evolutionary development, except for the vertebrates. Both books can be carried in the pocket, but have very weak bindings, and disintegrate within two years.

Edward Arnold's Introduction to Geology series consists of four large paperbacks, 'Fossils' and 'British Stratigraphy' by F. Middlemiss, 'Rocks and Minerals' by A. Leigh, and 'Physical Geology' by L. Knowles. All are in black and white, have a large format and simplified explanations. Together they do not complete a syllabus, and are expensive when compared to a single good general text, yet do not add a great deal to it.

Physical Geology overlaps the main Geography syllabuses, and books can often be borrowed from colleagues, but if money is available, then Holmes' 'Elements of Physical Geology' in its latest edition is still unrivalled as an introduction to this part of the work. Thos. Nelson is the publisher.

For either C.S.E. or 'O' level, the teacher is unlikely to cover the course well with a book expenditure of less than £3 per head.

'A' level examinations in Geology go far deeper into the subject, and here the need to supplement a general textbook is much greater. The two most widely available course books are 'General Principles of Geology' by J. Kirkaldy, published by Hutchinson, and 'Beginning Geology' by H. Read and J. Watson. Both are well written and adequately illustrated, the former without photographs. Neither has the depth in any section to allow it to be used as a sole source, and consequently for each major sub-section of the subject, further books need to be bought. Physical Geology requires greater depth, and 'Physical Geology' by Holmes satisfies most needs, although price and size are large. 'Minerals, Rocks and Gemstones' by Börner, published by Oliver and Boyd, covers that part of the

syllabus, and is a good analytical compendium for the
laboratory study of specimens as it is laid out
diagnostically. 'Stratigraphy of the British Isles' by
Bennison and Wright covers its topic fully, and has a
paperback edition, which for the economic makes it
preferable to Dorothy Rayner's similar volume. In
Palaeontology, Middlemiss has an expanded volume similar
in format to his 'O' level text. This is somewhat
unevenly written and drawn. Probably older texts are as
useful as any here, and Swinnerton's 'Fossils' in Collins
New Naturalist series is as good as any.

Mapwork at 'A' level generally requires a knowledge
of Geological Survey maps at 1" and/or $\frac{1}{4}$" scales.
Bradshaw and Jarman's volume, which I have already
mentioned, has been found the most satisfactory intro-
duction to these maps, and of course, a geographically
wide selection of map sets is needed - although single
copies can be used with pupils on a rotating basis for map
exercises.

Book costs for the 'A' level student are unlikely to
be less than £10 per head, and could be much more to equip
pupils really well for the searching questions set. In
addition, unless the teacher is able to build a good
collection and improvise much equipment, setting up costs
can be high, but in a future article I hope to show how
they can be mitigated.

REPORT ON FIELD MEETINGS TO HUNSTANTON AND WEST RUNTON

P. G. CAMBRIDGE*

Hunstanton (25 June 1972)

The cliff section at Hunstanton scarcely needs description. The upper part of the Carstone is unfossiliferous but shows excellent current bedding, and although showing differences in cementation sometimes the jointing is so perfect that the beach resembles a flagged pavement. The striking Hunstanton Red Rock bears little resemblance to the Gault clay, of which it is the stratigraphical equivalent. It and the lower part of the Lower Chalk is extremely fossiliferous. Large branching structures are common at this level. They have been described as a sponge - Spongia paradoxica - but are more likely to be traces of a burrowing organism. Between the Red Rock and the Paradoxica Bed, is a thin seam rich in iron oxides, which weathers out leaving a series of cavities. A recent boring for water near Hunstanton penetrated this junction and gave a copious flow of bright red water.

The upper part of the section was examined from the beach by means of field glasses and the upper part of the chalk was seen to be disturbed by cryoturbation. Above this there is a very thin soil cover. An interesting feature was a saucer shaped depression full of soil, with a line of oyster shells, apparently Ostrea edulis L, toward the northern end of the section where the height of the cliff decreases. This was assumed to be an occupation level of some kind but the site was too high to be reached from the beach.

After traversing the full length of the cliff section, a disused gravel pit near Docking (NGR 765358) was visited. The general section appears to be a brown loamy till, mostly covered by scree, overlain by a highly calcareous gravel with coarse sand lenses. A very high proportion of the sand and gravel is composed of chalk, and in places it has been cemented to form concrete like masses. The harder pebbles

* 258 Bluebell Road, NORWICH

are almost exclusively flint and a few fragments of iron-
stone (Neocomian?). In addition to the flint pebbles there
are also very large cylindrical flint masses penetrated by
numerous cavities. The section is topped by several feet
of shattered flints. Frost heaving, large solution pipes,
current bedding and other interesting features were well
represented.

     Finally a stop was made alongside the road in the middle
of an area of arable land just north of East Rudham (NGR
813300) to demonstrate the occurrence of numerous old pits
in this part of Norfolk. Each field seen contained at least
one such pit, situated well out in the middle of the field
and now hidden by bushes and well-grown trees. In most
cases these are old marl pits, tens of thousands of which
have been opened in Norfolk. The marl - clay rich in chalk -
was raised, often by means of a windlass from the deeper pits,
for spreading on the fields, and the pits were strategically
positioned to minimise the effort required to cart and spread
the material. The cost of treating land in this way today
is prohibitive and a similar effect is got by importing
ground chalk into the area and spreading it mechanically.
West Runton (23 July 1972)

     A previous visit to West Runton was described in
Bulletin No. 21. On the present occasion the afternoon was
spent examining cliff erosion and coast defences at
Overstrand, and the Maastrichtian Chalk erratics and over-
lying Quaternary deposits of Sidestrand. In the estuarine
sands and silts above the Stone Bed and 'Weybourne Crag',
thin flat pieces of cementstone occur which exhibit sun
cracks, and mollusc borings, etc., and sometimes contain
plant fragments and remains of shells. One of these pieces,
which are abundant on the beach, was broken open and proved
to contain a fine fossil example of the bryozoan Flustra
foliacea L.

Received August 1972

GEOLOGICAL SOCIETY OF NORFOLK

WINTER MEETINGS

October 26th, 1972

PRESIDENTIAL ADDRESS

Dr. R. G. West: "A state of confusion in Norfolk Pleistocene Stratigraphy"

7.30 Castle Museum

November 30th, 1972

Dr. F. J. Vine: "Geology of the Deep Ocean Floor"

7.30 Castle Museum

December 14th, 1972

A.G.M. and members slides

7.30 Castle Museum

January 25th, 1973

"Demonstration of techniques"

7.30 School of Environmental Sciences, U.E.A.

February 22nd, 1973

(To be confirmed)

March 29th, 1973

N. B. Peake, F.G.S.: "Maastrichtian and Danian in N. W. Europe"

Arts Block I, U.E.A. 7.30

April 26th, 1973

"Members specimens"

Arts Block I, U.E.A. 7.30

Members are reminded that subscriptions (£1) are due on 1st. October 1972 and that a bankers order is a convenient way of paying.

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The Geological Soceity of Norfolk exists to promote the study and knowledge of geology, particularly in East Anglia, and holds monthly meetings throughout the year.

Visitors are welcome to attend the meetings and may apply for election to the society. For further details write to the Secretary, Castle Museum, NORWICH, NOR 65B.

Copies of this Bulletin may be obtained 60p (post free) from the Society at the Castle Museum, NORWICH, NOR 65B; it is issued free to members.

Also available at 75p (post free) is "The Geology of Norfolk", a 108 page book describing the geology of the county, reprinted by the Society in 1970; members of the Society may buy one copy only at 40p.

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BULLETIN OF THE GEOLOGICAL SOCIETY OF NORFOLK

No. 23

CONTENTS INCLUDE:
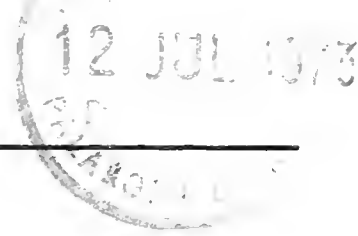
EDITORIAL

        With this edition we say goodbye to Brian McWilliams
as our Secretary, happily he will still be with us in his
new role as President of the Society. We welcome
Dr. Christopher Aslin as our new Secretary, and also move
our normal venue for lecture meetings from the Castle
Museum to the University of East Anglia. Our thanks are
due to Brian for his several years as Secretary, which
culminated in excellent attendances at the Castle Museum
for the autumn lectures. It is hoped that similar support
will continue at our new location.

        Dr. Richard West, our outgoing President, has written
a summary of his Presidential Address which we are very
happy to publish. This will provide a permanent record of
a very stimulating lecture, which aroused many questions.
The continuing series on Geology in education has this time
a contribution from the Open University, where our
contributor Dr. Wilson helped write the very interesting
course. The Carstone is also investigated in two quite
different ways by our other contributors, and for the first
time we include a Secretary's Report for the year 1972.

        Bulletin No. 24 will be issued in September 1973.
Contributions should be sent to me as soon as possible,
and no later than July 31, 1973.

        Will contributors please note that manuscripts are
acceptable in legible handwriting, although typewritten
copy is preferred. In either case it would be a great help
if details of capitalisation, underlining, punctuation,
etc., in the headings and references (particularly) could
conform strictly to those used in the Bulletin. Otherwise
publication may be delayed.

Illustrations intended for reproduction without redrawing should be executed in thin, dense, black ink line. Thick lines, close stipple, or patches of black are not acceptable, as these tend to spread in the printing process employed. Original illustrations should, before reproduction, fit into an area of 225 mm by 175 mm; full use should be made of the second (horizontal) dimension, which corresponds to the width of print on the page, but the first (vertical) dimension is an upper limit only. All measurements in metric units, please.

R.S.J.

A STATE OF CONFUSION IN NORFOLK PLEISTOCENE STRATIGRAPHY
(a summary of the Presidential Address for 1972, delivered
October 26, 1972)
R. G. WEST*

In the days of Clement Reid (1890) the Pleistocene
started near the top of the Cromer Forest Bed Series, at
the point where the oncoming of cold conditions was
indicated by the presence of arctic plants (Arctic Fresh-
water Bed of Clement Reid). Nowadays the Pliocene/
Pleistocene boundary is placed at the base of the Red Crag,
so that the Pleistocene includes the thick series of marine
sands and silts which comprise the Red, Norwich and Weybourne
Crags. However, here I shall revert to Reid's definition,
and discuss the stratigraphy of the glacial part of the
Pleistocene, i.e. later than the Cromer Forest Bed Series.
Suffice it to say that there is also a state of confusion
in the Forest Bed and Crag part of the Pleistocene, with
the sequence of climatic stages and their correlation with
the continent not yet clearly defined.

The lower limit of the glacial Pleistocene can be taken
for our purpose to be the top of the Cromer Forest Bed
Series. The boundary between the Cromer Forest Bed Series
and the earliest tills can be seen around the coast from
Sheringham to Corton. The upper limit can be taken to be
the glacial deposits and periglacial phenomena associated
with the last (Devensian, i.e. Weichselian) glaciation.
These glacial deposits include the Hunstanton Till of the
north Norfolk coast, and the periglacial phenomena include
the stripes and polygons of the Breckland and the frost
mounds of central and west Norfolk. The form of these
effects is closely related to the present topography,
indicating that there has been little change since the last

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glaciation.

The problem which concerns us here is what happens
between these limits. How many glacial advances were
there, and what did each advance deposit?

There are two kinds of fixed points available in
considering the sequence: till sheets which extend over
a distance and can be ascribed to one glacial advance
(such as the blue chalky boulder clay of central and east
East Anglia) and interglacial deposits which show a
regular and well-defined sequence of pollen assemblage
zones (such as the Hoxnian interglacial vegetational
sequence (West 1972)). The occurrence of a well-defined
till sheet, underlain by or overlain by an interglacial
deposit with a well-defined vegetational sequence, offers
a very satisfactory fixed point in unravelling the glacial
sequence.

Let us first take the fixed points in the sequence,
and then see how problematical deposits have been fitted
in by various authors.

Starting at the coast of Corton, we have the well-
known tripartite sequence: Norwich Brickearth, Corton Sands,
Lowestoft Till. Beneath the lower till occur peat deposits,
with a fossil content indicating a correlation with the
Cromerian at West Runton. The present evidence indicates
that this tripartite sequence belongs to one cold stage
(the Anglian), for there is no evidence that temperate
conditions intervened at any time in the sequence.

Most students of the Pleistocene would agree that the
Lowestoft Till extends inland to Hoxne, the type site for
the Hoxnian temperate stage, so that the Anglian cold stage
is evidently between the Cromerian and Hoxnian temperate
stages. The Hoxnian has a very characteristic vegetational
sequence, and its deposits have been found overlying
Lowestoft Till at other sites in Suffolk, e.g. Saint Cross
South Elmham. They have also been found on the bluish
chalky boulder clay of central Norfolk at Barford (Cox

and Nickless 1972), from which a pollen sequence has been
studied by Miss L. Phillips, so that this till must also
belong to the Anglian stage. According to Banham (1970)
the tills of the coastal sections of north-east Norfolk
are again to be included in this stage.

It is in the consideration of the post-Hoxnian sequence
that controversy arises. The view that it was followed by
an ice advance (Gipping advance of the Wolstonian cold
stage), then a further interglacial (Ipswichian temperate
stage), and finally the last glaciation, has been contested
by Cox and Nickless (1972), who consider that there is no
evidence in central Norfolk for a Wolstonian advance, and
that the Hoxnian deposits in the area accumulated during
the early part of an interglacial, the latter part of which
may be represented by the Ipswichian deposits of other
parts of East Anglia. Here we may point out that the
vegetational sequence of the Ipswichian is very different
from that of the Hoxnian, so that Ipswichian deposits can
be distinguished from Hoxnian deposits.

An important point here is that at Hoxne the temperate
interglacial deposits are succeeded by beds with a flora
indicating cold conditions - a flora which must be included
in the following cold stage. At several sites temperate
Ipswichian sediments are underlain by sediments with a herb
flora, which must be included in the preceding cold stage.
We therefore have clear evidence of a cold stage between
the Hoxnian and Ipswichian, and it seems reasonable to
correlate this with the Wolstonian. Whether any glacial or
periglacial deposits can be referred to this cold stage in
East Anglia is discussed later.

Before we do this it is necessary to consider briefly
the stratigraphical position of Ipswichian deposits in
Norfolk. The Mundesley River Bed lies in a valley cut in
the glacial sequence. At Beetley, interglacial deposits lie
on coarse flint gravel arranged in a moundy fashion, within
a valley. At Swanton Morley, interglacial deposits occur

below terrace gravels of the Upper Wensum. At Wortwell,
interglacial deposits lie in gravels within the Waveney
Valley. The first three of these sites have been studied
by Miss L. Phillips, and the results are in course of
publication.

All these Ipswichian deposits lie within valley
systems, which must have largely originated before the
Ipswichian. Hoxnian deposits may lie on interfluves
(Hoxne) or in valleys (Barford). Where they lie in valleys,
the valleys are associated with deep subglacial channels
of Anglian age, thus indicating that the present valleys
at these sites follow trends set by the old subglacial
channels.

Thus the events between the Hoxnian and the Ipswichian
include a cold period and a period of downcutting. The
problem is - are there any glacial or periglacial deposits
associated with this interval?

According to Baden-Powell (1948) and West and Donner
(1956) the Gipping Till, identified on a basis of erratics
and stone orientation, belongs to this interval.
According to Bristow and Cox (1973), there is only one
chalky boulder clay and this is pre-Hoxnian. According
to Straw (1965), the Marly Drift of north Nortolk, a very
chalky boulder clay, belongs to the cold stage between
the Hoxnian and Ipswichian. According to Cox and Nickless
(1972), all the glacial deposits in central Norfolk belong
to the Anglian. At Hoxne, there are coarse gravels over-
lying the interglacial deposits. These evidently post-
date the deposits with a cold flora and pre-date the period
of downcutting (West 1956); they may be periglacial (or
glacial?) sediments of the cold stage between the Hoxnian
and the Ipswichian. At Mildenhall, a till occurs above
interstradial deposits which are probably post-Hoxnian
(Holmes 1971).

It has also been suggested that the erratic-poor
flint gravels of Norfolk may be placed in the Wolstonian

cold stage. Thus Straw (1965) associates the Blakeney-
Holt gravels with the Marly Drift. Sparks and West (1964)
associated the same gravels with the Wolstonian. On the
other hand Cox and Nickless (1972) place the flint gravels
of central Norfolk in the Anglian.

It is clear from the fore-going that the following
questions need to be answered before these problems can
be solved.

1.   Js the Marly Drift pre- or post-Hoxnian?
2.   Are the deposits at Hoxne and Mildenhall mentioned
      above Wolstonian in age?
3.   Can the gravels or Norfolk be differentiated on
      their erratic content? (There should be type-
      sites for particular gravels.)
4.   If they can be differentiated into, for example, a
      "cannon-shot" type and types with different
      erratic suites, how will the gravel stratigraphy
      fit into the till and interglacial stratigraphy?

However, in spite of these doubts associated with the
Hoxnian to Ipswichian stratigraphy, there seems to be
general agreement on the last (Devensian) glaciation
sediments of Norfolk. They include the Hunstanton Boulder
Clay and its associated outwash, and certain low terrace
deposits of the valleys.

The final point of confusion attends the matter of
correlation of the cold stages with those of the
continent. According to those who have studied the
vegetational history of interglacial stages in north-west
Europe, the Hoxnian is to be correlated with the
Holsteinian of north Europe, and the Ipswichian with the
Eemian. It follows that the Anglian cold stage is to be
correlated with the Elster, and the Wolstonian with the
Saale. Other views have recently come forward, Bristow
and Cox (1973) have suggested that the Anglian is to be
correlated with the Saale, as they consider there is only
one widespread chalky boulder clay predating the last

glaciation till.   Woodland (1970) considered that the
"Great Chalky Boulder Clay" of East Anglia was likely to
be of the last glaciation age, on account of the
similarity of the subglacial drainage system and the
topography with last glaciation regions of Denmark.
These views need to be carefully considered, but it is
difficult, at least for me, to see how they can overturn
the substantial amount of biostratigraphical evidence on
which the interglacial correlations are based.   A final
word of warning is necessary on the matter of correlation
with the continent.   It is by no means clear that the
sequence of temperate and cold stages is in anything like
its final form in East Anglia or on the continent.   It may
be far more complicated than we now know.   The present
state of correlation is necessarily based on present
evidence, but we should always keep an eye open for
further complications.

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A POSSIBLE MECHANISM FOR INVOLUTIONS IN THE NAR VALLEY

H. EVANS*

Introduction

Involutions are a common feature of periglacial areas,
and normally occur in the finest grades of sediment. Those
of the Nar Valley are distinctive because they occupy a
surficial zone in which intensely weathered Carstone has
been reduced to a mass of blocks in a matrix of sand. The
involutions, which lie dominantly within this weathered
mass, appear to have partially lifted joint blocks of
Carstone away from their attachment to in situ bedrock.
Some involutions also appear to have been affected by
solifluction which has resulted in collapsed involuted
forms.

Description

The area consists of an east-west striking ridge of
Carstone on the northern side of the Nar Valley (Fig.1).
Against the southern side of this ridge are banked a series
of sands and gravels up to 8 metres in thickness. These
sediments thin rapidly to the west and across the ridge
itself. The site studied was in the Blackborough End
Gravel Pit and extended for 12 metres on a NNW - SSE
alignment.

Succession (see Fig. 2)

G.   Top soil.   0.67 m

F.   Head deposits of angular to sub-rounded
     fragments of Carstone within a matrix of well
     washed medium-grained sands. Many of the
     flints have been frost-fractured in situ.   1.34 m

E.   A mixed series of both sorted and unsorted
     buff sands which form thin lenticular masses.
     Sorting is indicated by fine laminae of dark
     brown granular Carstone.

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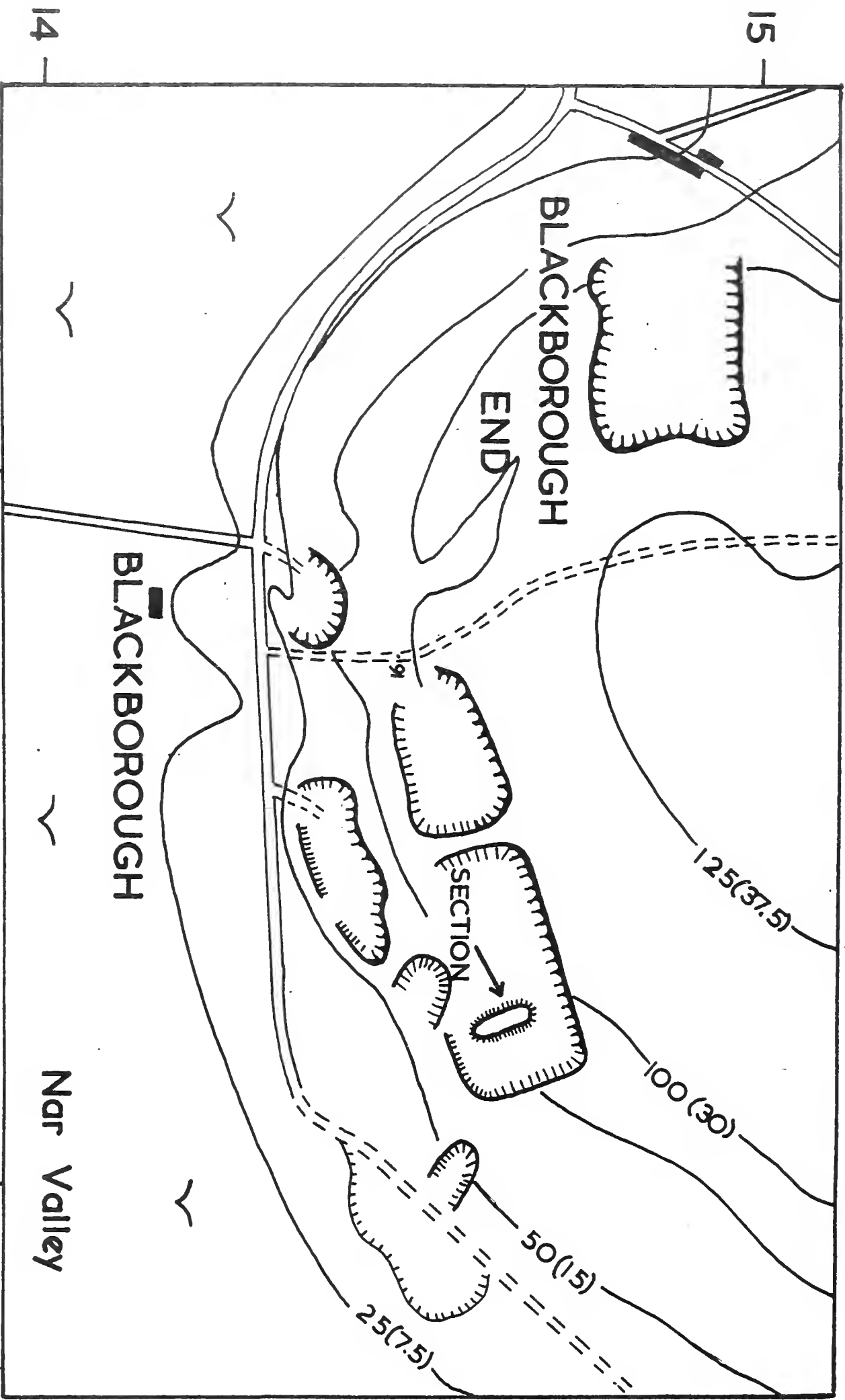
Fig. 1. Sketch-map of the Blackborough area. National Grid 1km. co-ordinates are shown. Contours are given in feet, metric equivalents in brackets.

D.   Medium to coarse well washed light yellow
      sands with small scale cross-bedding over-
      lying an erosion surface.   0.26 m

C.   A bed of intensely weathered Carstone which
      has been reduced to coarse red-brown
      granular sand with a high limonitic fraction.
      Alternating red and yellow sandy bands are
      noted in part of the bed which probably form
      part of a structural B Horizon.   1.40 m

B.   The massive Carstone varies in texture from
      limonitic boxstones at the base to a
      weathered rubbly fraction at the top of the
      bed.   2.65 m

A.   A transition bed of banded yellow and red
      coarse sands with some nodular bands of
      Carstone. This bed marks the base of the
      Carstone with the Sandringham Sands below.

The massive Carstone has been subjected to intensive
weathering under periglacial conditions in which macro-
gelivation (Tricart 1956) has fully exploited both joints
and bedding planes. This has resulted in block disinte-
gration within the Carstone subsurface, and to a lesser
extent granular disintegration. The differential effect
varies with the lithology since the limonitic rinds of
box-stones are reduced to well defined angular blocks
highly resistant to further freeze-thaw. In contrast,
rubbly Carstone blocks are often honeycombed in texture
and present an open system for granular disintegration.
The size of block varies with the intensity of weathering,
but an average size within the upper 30 cm. of the
Carstone would be about 6 x 3 x 1 cm.

The granular Carstone of Bed C forms a deeply
weathered zone on the lower slopes of the ridge. In this
particular section the sediments are largely disrupted by
cryoturbation but some traces of alternating bands of
yellow sand and ferruginous clayey sands were found. The

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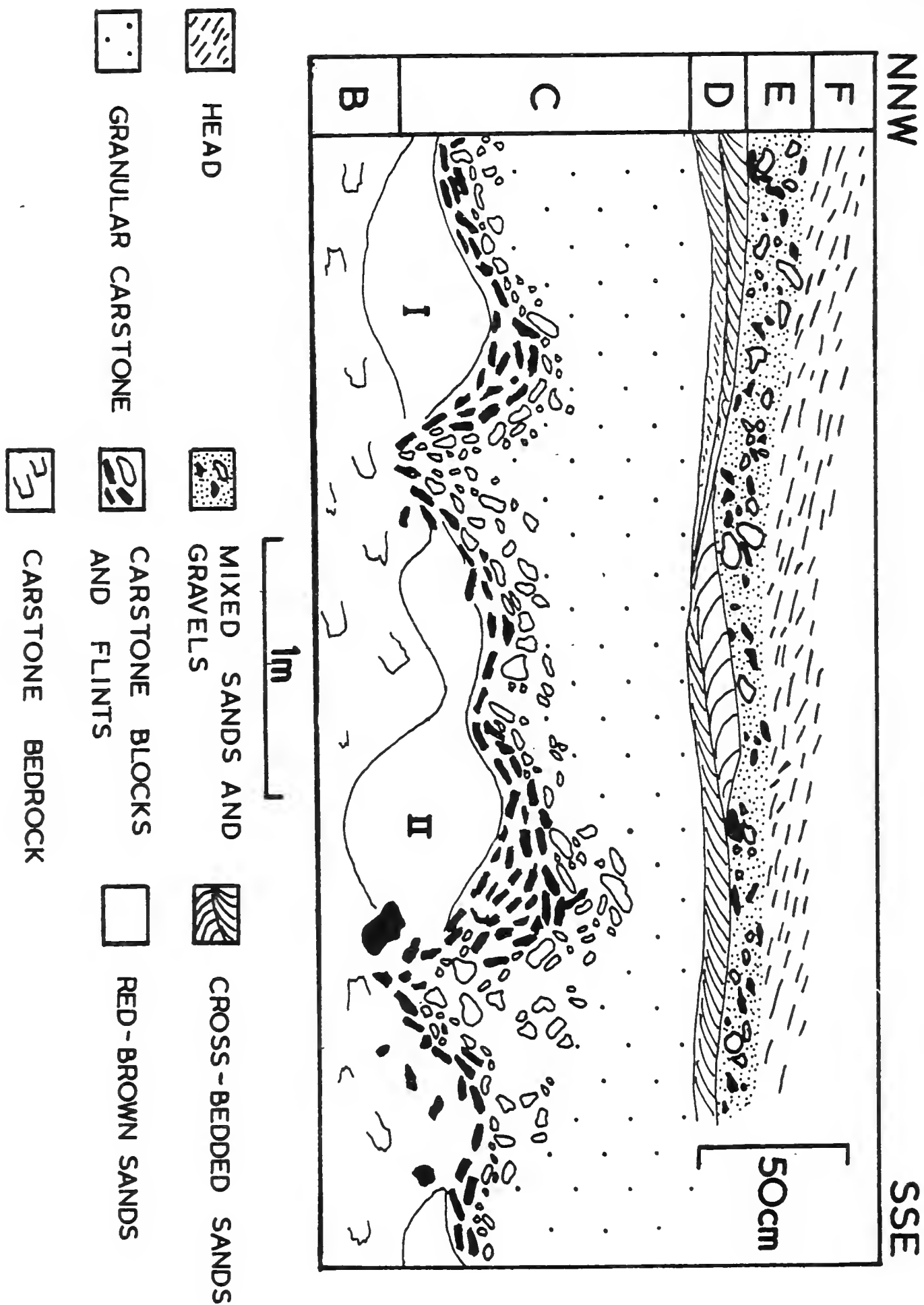
Fig. 2. Measured drawing of involutions within the
         northern part of the section.

latter are plastic when wet. A comparison with other
sections showed that the banded sands were a product of
weathered Carstone. Microscopic examination of the
yellow sands revealed a high proportion of fractured quartz
grains, which indicated that mechanical breakage in situ
had been effective. It is possible that this bed is a
textural B Horizon which formed when the slope was fully
vegetated and stable.

The cross-bedded buff sands of Bed D show considerable
lateral variation throughout the quarry. In this section
the bed is in contact with an erosion surface, but else-
where it can overlie a sequence of poorly sorted outwash
sands and gravels. The mixed sands of Bed E pass up to
subangular to subrounded Carstone which probably represents
a solifluction head. Examination of the Carstone within
this bed showed a high percentage of conglomeratic Carstone
which was probably derived from higher up the succession to
the north, and transported downslope under active slope
processes.

Periglacial Structures

The involutions extend for some 12 metres within the
granular Carstone of Bed C along a NNW - SSE alignment.
The term involution core is interpreted as that part of
the surficial layer where sag or U-shaped deformation
(Watson 1965) has developed, while adjacent anticlinal
flexures, which partly enclose the involution core, are
referred to as core walls. The involutions have no surface
expression within this section but show an increasing
degree of instability to the SSE with resulting deformation.

Involutions in contact with the bedrock (Fig. 2)

Length of section: 4.5 metres.

1.   The involution cores consist of well compacted flinty
     gravels and cobbles within a matrix of medium red-
     yellow and red-brown sands. The cores are open-ended
     at the contact with the in situ bedrock of Bed B.

2.   The core walls are composed of well aligned weathered
      blocks of Carstone capped by aligned flint cobbles,
      many of which have been frost fractured in situ. The
      high dip of blocks within south facing core walls give
      a recumbent form to the anticlinal flexures, the latter
      having an amplitude of 80 cm.

3.   The recumbent structures overlie elliptical pockets of
      red-brown sands (Fig.2, I and II).

Involutions detached from the bedrock (Fig. 3)

Length of section: 5.0 metres.

1.   Only one involution core is observed within this part
      of the section.

2.   The amplitude of structures is much reduced compared
      with those described above, and is generally less
      than 50 cm.

3.   The involution form is mainly lacking and replaced by
      a complex sequence of overturned Carstone blocks with
      some evidence of décollement towards the SSE of the
      section.

4.   Bed C1 (Fig. 3) consists of red-brown sands with
      scattered Carstone blocks and fine gravel, the sands
      are similar to those of the elliptical pockets (Fig. 2,
      I and II). The basal 20 cm is made up of dark blue-
      brown granular Carstone indicating recent weathering
      in situ. Bed C1 has been disrupted by yellow-red
      gravelly sands in the form of a discrete trail and
      two elongate pockets.

Interpretation

        There have been many papers describing the mechanics
of frost-heave in the grained sediments, but few for
coarser material. Previous workers have attributed the
uplift of weathered bedrock to different mechanisms. These
include folding due to weathering (Campbell 1906), drag or
slide due to glacial movement (Sardeson 1905), upheaval due
to frost action (Sardeson 1906), and uplift due to hydro-
laccoliths (Bradshaw and Ingle-Smith 1963). The following
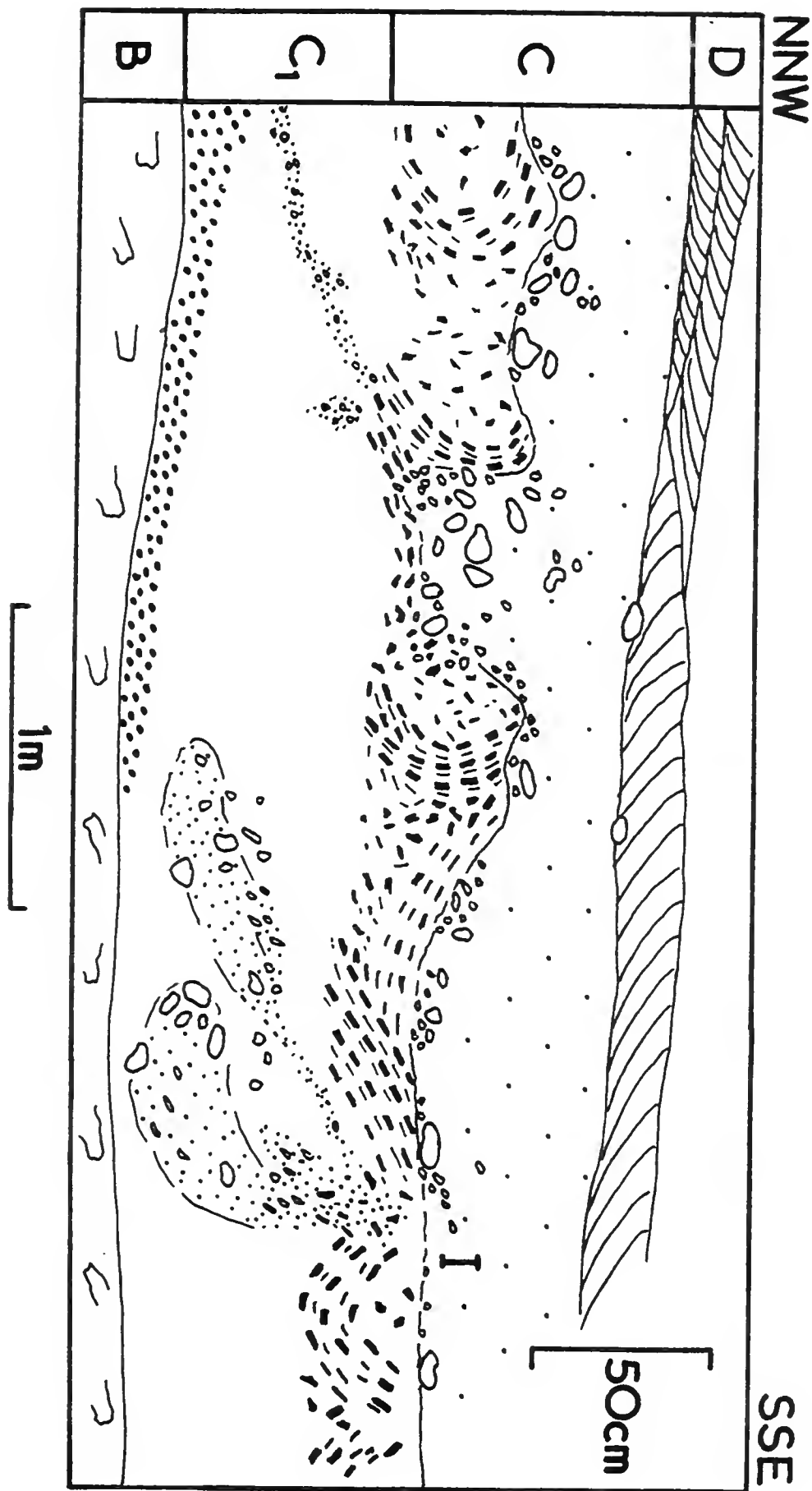
Fig. 3. Southern part of section showing main features
of deformation within the involuted layer. Key
to beds as for Fig. 2. Heavily dotted area,
Basal Bed Cl, denotes granular Carstone.

account considers forceful intrusion and differential
sorting as the possible mechanism for involutions.

The subsequent removal of material from this site
showed the disposition of involutions in many stages of
development along the upper surface of in situ bedrock.
It was found that involution cores were subjacent to
downward penetrating irregularly shaped pockets of red-
yellow sands with vertically aligned cobbles and gravels.
One section revealed four descending pockets, the largest
being 0.40 x 0.25 metres, within a horizontal distance of
2.5 metres.

At the point of contact with the Carstone surface
the weathered blocks were depressed by the lodgement of
descending sand and gravel pockets, and formed the
subsequent involution core, (Figs. 4a and b). The combined
effect of this at several points of contact was to produce
low amplitude anticlinal flexures, the core walls, as a
result of compensatory upward movement. Apart from some
granulation within the core walls there was no evidence to
indicate partial uplift from the segregation of fine grained
masses. The amplitude of core walls was never greater than
25 cm. Similar successions were examined in order to
clarify the relationship between the Carstone subsurface
and the initial formation of involutions. It was found
that:

(i)   Weathered blocks greater than 2.0 cm in thickness
      resisted the forceful penetration of gravels.

(ii) Where vertical jointing had been greatly weathered
      the penetration or collapse of overlying gravels
      formed "Neptunean dykes" up to 38 cm in width.

(iii) Partial uplift appeared to be most effective where
      shattering had increased the overall joint system,
      and reduced block thickness to less than 1.5 cm
      (see shattered Zone Fig. 4b). In this state the
      forceful lodgement of gravels was restricted to a
      depth of 35 cm by the permafrost table.

a.
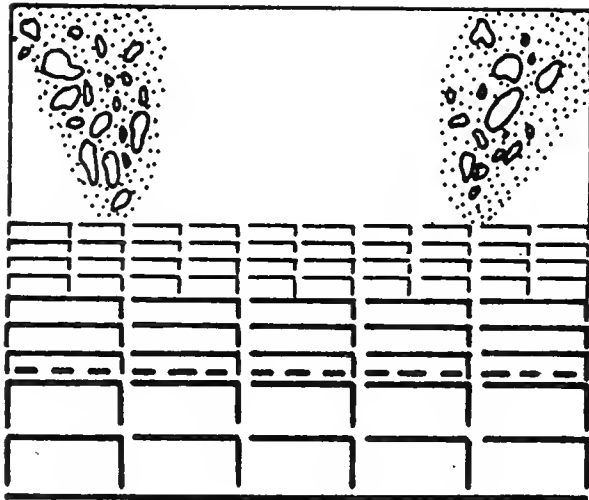
SURFICIAL LAYER OF
GRANULAR CARSTONE

ZONE OF SHATTERED
CARSTONE BLOCKS

PERMA·FROST TABLE

MASSIVE CARSTONE

b.
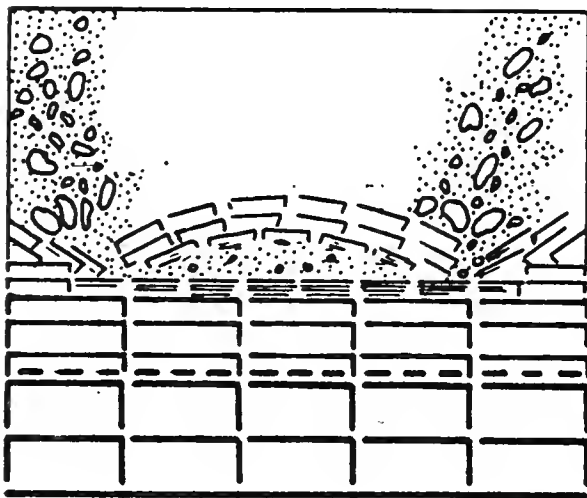
Fig. 4. Schematic sections illustrating a possible mechanism for involutions.

(a). The downward migration of sand and gravel pockets in advance of a freezing surface.

(b). The partial uplift of shattered blocks and proliferation of the sand fraction.

Further development of involutions appeared to be relative to the lateral migration of sands and finer gravels away from the involution core (Fig. 4b). The grade of the migrating material was effectively controlled by the close disposition of blocks within the base of core walls, while depleted involution cores became highly compacted with gravels and cobbles. It is advocated that lateral migration resulted in the eventual formation of elliptical pockets, and that these acted as centres for ice segregation and differential heave (Fig. 2, I and II).

Samples were taken from both the periphery and centre of these pockets in order to determine the percentage of fines (less than 0.074 mm), and to compare them with the sediments of involution cores and Bed C.

Bed C (fines averaged 2.5%).

Involution cores (fines less than 1% in all samples).

	Periphery	Centre of Pocket
Fig. 2, I.	1.5 - 2.0%	2.6%
Fig. 2, II.	2.0%	3.3%

Microscopic examination of all grades sieved revealed aggregates of quartz grains cemented by limonite, and indicated that the fines were probably under-represented in the sieve analysis. The results not only indicate that the percentage of fines increase downwards, but there is a significant increase from depleted involution cores to the centre of pockets.

It is considered that the dominant mechanism during the initial phase was the downward migration of gravels in advance of a freezing surface. A.L.Washburn (1950) has proposed cryostatic pressure for such a process in patterned ground, but those studied have no surface expression. To some extent cryostatic pressure is envisaged but accompanied by differential sorting within the active or surficial layer (Sharp 1942). Since the percentage of fines increase downwards it is likely that these migrated with the freezing surface (Corte 1963),

with additional fines also produced at the permafrost
table since moisture tends to concentrate at this surface.
This is particularly evident from the underlying pockets of
core walls.

Since the involution cores terminate abruptly at the
bedrock surface it is unlikely that the compensatory
uplift of core walls would have been great. Observations
of the initial height of vertical movement is about 25 cm.
Therefore the progressive uplift of blocks has probably
resulted from the lateral migration of sands from
involution cores to form ice segregation centres (Fig. 2,
I and II). Repeated freezing and thawing within these
centres would segregate the fines necessary for
differential heave. S. Taber (1929) regards 3% fines as
too small for differential heave, but T. L. Péwé (1962)
considers such a figure minimal for heaving to occur, the
latter does not indicate the degree of heave taking place.
This author considers that the relationship of involution
form to segregated pockets suggest differential heave as
a likely mechanism rather than one which is pure
congelistic.

The deformation of involutions and subsequent collapse
of core sediments in Fig. 3 can be partly ascribed to
active slope processes. The Carstone subsurface has been
subjected to a greater depth of weathering resulting in
slope retreat with a downslope angle of two to three
degrees. A distinct break in slope separates those
completely detached. Therefore the marked structural
trend of deformed involutions down-slope is probably the
result of solifluction under conditions of saturation
during the spring-summer thaw.

The recently weathered granular Carstone (Bed C1,
Fig. 3) confirms that weathering continued to be an
active process after deformation, and to some extent
explains the apparent height to which blocks appear to
have become detached. It is also considered that

detachment was contemporaneous with solifluction since
slip would have possibly effected the lateral spread of
segregated centres below the involution walls. The red-
brown sands of Bed C1, Fig. 3 are similar to those found
in Fig. 2, I and II. These sands (Bed C) have been
intruded by two pockets of gravels and cobbles within a
matrix of red-yellow sands, the latter being similar to
those found in all involution cores within the section.
The pockets have sharp contacts, and both are aligned
upslope and sub-parallel to a trail of similar sands.
There is a marked absence of cobbles capping the collapse
structures in that part of the section (Fig. 3, I).

The sharp contacts of these pockets indicate that
entombment was rapid. Therefore under conditions of
extreme saturation the medium coarse sands of involution
cores would be less cohesive and heavier (Williams 1959).
This state of instability is likely to be activated by
slip within the surficial layer so that the collapse of
involutions cores would result from the rapid downward
migration of sands into Bed C. S. Dzulynski et al. (1964)
considers that such disturbances are caused by spontaneous
liquefaction under hydrostatic pressure. Similarly, P.H.
Keunen (1958) proved experimentally that canoe-shaped
structures are indicative of rapid entombment from
vertical motion of the 'load-cast' type.

The additional water required for supersaturation is
relative to the height of the water-table. Exposures in
the northern part of the ridge reveal large fissures, up
to 1.0 metres wide at a depth of 6 metres, which have
developed along joint planes. These would allow sufficient
circulation of ground water to carry heat to considerable
depths, thus effecting an extensive thaw during the summer
months.

Conclusions

1.   The involutions were initially formed, under peri-
     glacial conditions, from the downward migration of

sands and gravel pockets in advance of a freezing surface. The impingement of these pockets on the Carstone surface resulted in the depression of weathered blocks to form a site for the involution core. The partially uplifted blocks of core walls are in part a compensatory response to the lodgement of the core, but to a greater extent from the lateral movement of sands away from involution cores to form centres for ice segregation. Differential heave from repeated freezing and thawing within these segregated centres uplifted the involution walls through a greater height.

2.   The involutions were then subjected to solifluction which deformed the existing structures, and resulted in the collapse of core sediments into the bed below. The rapid entombment of these sediments was probably due to vertical motion, the 'load-cast' type, under conditions of supersaturation.

The peculiar form of these involutions was confined to a small area of Blackborough Pits, and is therefore regarded to be of local significance only. The association of deep weathering of joints to form fissures, ice wedges, frost kettles and stone stripes is under review.

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THE BASE OF THE CARSTONE AT HUNSTANTON

R. W. GALLOIS*

Introduction

The familiar rusty-brown Carston of Hunstanton Cliffs
needs little introduction to the student of East Anglian
geology. The details of the lithology of the Carstone end
of its junction with the overlying Red Chalk have received
considerable exposure in the geological literature. By
contrast, the base of the Carstone and the nature of its
contact with the Snettisham Clay, because of its poorly-
exposed position low down on the foreshore, has rarely been
described. Even the few accounts that do exist leave
considerable doubt as to where the Carstone ends and the
underlying clays begin.

Rose (1862, p.235) described the Carstone on Hunstanton
beach as a 'breccia', saying that it had been considered to
be the base of the Lower Greensand but that at low water he
had found a non-brecciated bed beneath the breccia and saw
this bed resting on a clay (presumed at that time to be the
Kimmeridge Clay).

Wiltshire (1869, p.189) recorded a nodule bed, made up
of two distinct types of nodule, at the junction of the
Carstone and the clay. The first type of nodule, of unstated
lithology, contained numerous Ammonites Deshayesi and
occasional A. Cornuelianus (Prodeshayesites and Cheloniceras
of modern authors); the second type of nodule consisted of
masses of ironstone and yielded A. Cornuelianus and many
bivalves. He concluded from these faunas that the lowest
part of the Carstone was equivalent in age to the base of
the English Lower Greensand.

Keeping (1883, pp. 33 and 57) reviewed this and other
collections from the same beds and gave further details of

* Institute of Geological Sciences, London S.W.7,
  published by permission of the Director.

lithologies and faunas of the nodules. The first type he
described as rolled phosphatized casts containing Lower
Aptian ammonites which he considered to be entirely derived.
The second type consisted of concretions of dark-coloured
ferruginously-cemented fine-grained sandstone 'as big as
large cannon-balls' and 'crowded with casts of fossils'.
The fossils were mostly bivalves, but included fragments
of an ammonite described as 'Hamites or Ancycloceras,
small species with a double row of spines along the back'
(p.33).

Whitaker and Jukes-Browne had little to say about the
nature of the base of the Carstone in the Survey memoir on
the borders of The Wash (1899), although the underlying
clays had by now become recognised as 'Lower Greensand' in
age and were assigned by them to the Snettisham Beds (p.6).

The first, and possibly the only, published
description of a section through the base of the Carstone
at Hunstanton is that of Lamplugh (1899, p.20) who recorded
about two feet of 'pebbly yellow Carstone with yellow
phosphatic fragments and fossiliferous dark brown phos-
phatic nodules', the nodules containing A. Deshayesi,
probably underlain by 'green clayey sand, with scattered
coarse pebbly grains'. He concluded that the fauna of the
nodules was at its proper horizon and that the lower part
of the Carstone was equivalent in age to the upper part of
the Atherfield Clay or to the lower part of the Hythe
Beds (p.21). These are clearly the same nodules as those
containing Keeping's derived fauna, but no mention is made
of the iron-grit nodules.

More recently, Casey (1961, p.571) has re-examined
many of the old collections from the phosphatic nodule bed,
together with material collected over many years by Mr.
Hamon LeStrange of Hunstanton, and has shown the ammonite
assemblage to be composed of two faunas, both Lower
Aptian in age, from the Zones of Prodeshayesites
fissicostatus and Tropaeum bowerbanki.

In 1970 the Institute of Geological Sciences drilled a cored borehole at Lodge Farm, Hunstanton (TF 6857 4078), about 1½ Km ESE of the beach sections described below, to examine the Lower Cretaceous sequence. The cores threw little light on the nature of the Snettisham Clay - Carstone junction, and the base of the Carstone was placed at a change from pebbly oolitic clays to pebbly oolitic sands. No phosphatic nodule bed was seen and the section appeared to bear little relation to those of the published literature.

This was the rather unsatisfactory situation that led Mr. LeStrange generously to hire a mechanical digger to expose part of the Snettisham Clay - Carstone contact. As a result, about twenty members of the Geological Society of Norfolk, together with assorted shovels, sieves and a JCB 3C, gathered on Hunstanton beach at low tide on the morning of October 22nd., 1972.

Stratigraphy

The first and second attempts to obtain sections, a little to the south and to the north of the pier respectively (Fig. 1), were at spots indicated by Mr. LeStrange as being on the line of outcrop of the base of the Carstone as he remembered its position when it had been visible in the 1930s. Both excavations passed through a metre or more of beach sands into waterlogged flint gravels and the holes collapsed.

A third excavation adjacent to the outer Carstone reef (TF 6714 4160) was more successful and proved weathered pebbly Carstone resting on very pebbly dark grey sandy clays containing many limonitized ooliths. No phosphatic nodule bed was seen and although the section could be matched in some detail with that of the Hunstanton Borehole, this was not particularly helpful.

The fourth, and final, section dug adjacent to the same reef (TF 6715 4177) was the most successful and work in it, and on the spoil derived from it, occupied the
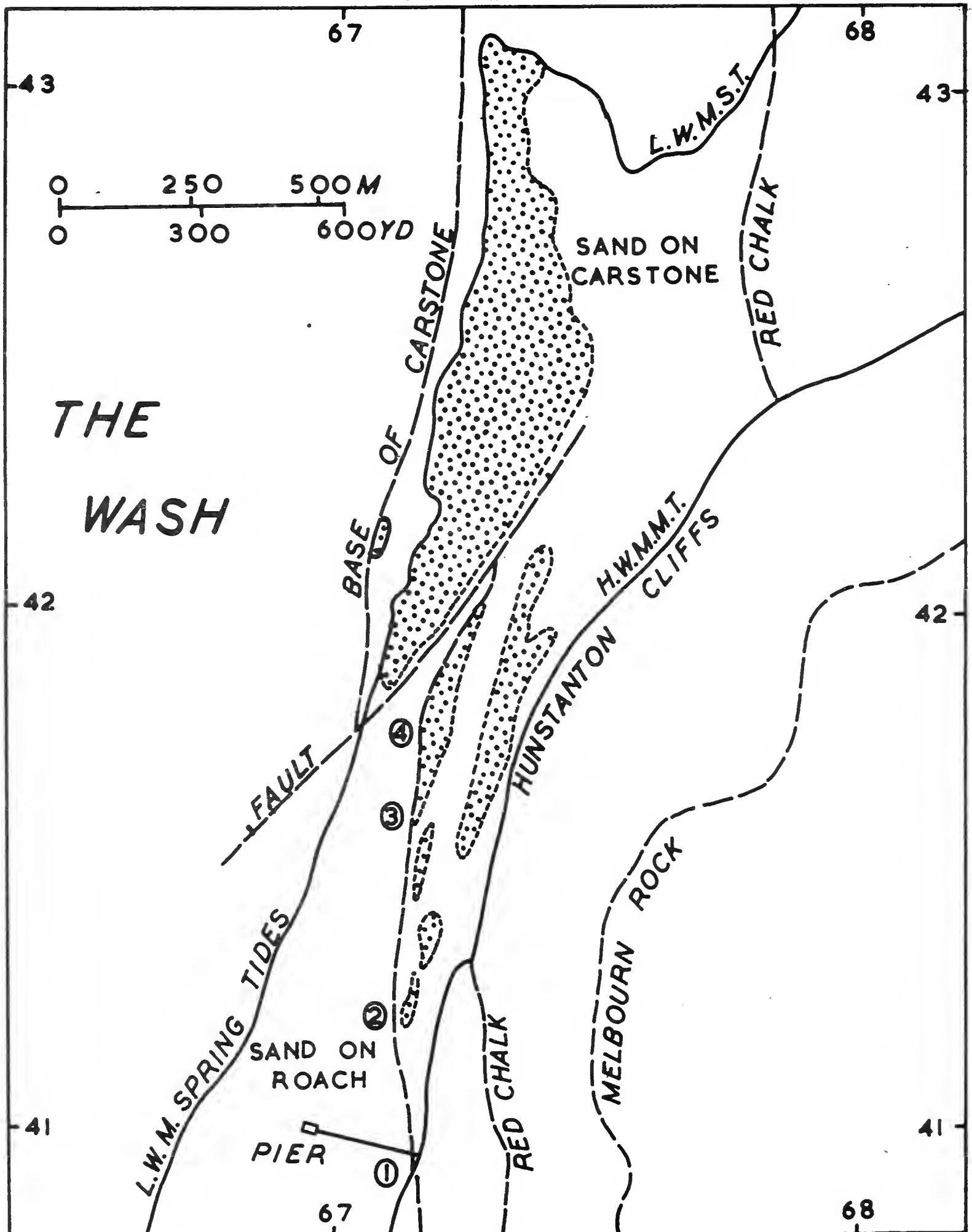
Fig. 1. Geological sketch map of Hunstanton Beach in 1972 showing Carstone outcrops (stippled) and sites of excavations 1 to 4.

greater part of the day. A trench about 0.6m x 2.5m x
3.2m deep was excavated and the following section
recorded:

  Recent beach sand   0.30 m

5. Fine-grained orange-brown, moderately pebbly,
  oxidised and rotted ferruginous sandstone 0.30 m

4. As above but very pebbly and including
  widely spaced (0.5m to 1.0m apart) dark
  brown generally well rounded phosphatic
  nodules (up to 0.1m across, but mostly 0.02
  to 0.03m), some of which contained worn
  specimens of ammonites; ferruginous seepage
  ·at base   0.15 m

3. Dark grey sparsely pebbly, moderately oolitic
  (chamosite, largely oxidised to limonite)
  intensely burrow-mottled clay   0.76 m

2. Dark grey very pebbly, moderately oolitic,
  slightly sandy clay; very sharp plane base 0.30 m

1. Pale and medium grey intensely burrow-mottled
  fine-grained sands and very fine-grained
  clayey sands; burrow fills of fine and medium-
  grained greenish yellow sand extend down for
  about 0.5m from the base of Bed 2; fragments
  of coalified wood scattered throughout;
  widely spaced dark greyish brown sandy
  ferrugino-phosphatic nodules, mostly burrow
  fill shapes, up to 0.2m across and some
  containing moulds of small bivalves, rarer
  gastropods and bits of wood, occur in the
  lowest 0.5m (not seen _in situ_); small irregular
  sandy pyrite concretions occur more rarely at
  about the same level   1.37 m

  Bed 5 is a continuation of the outer Carstone reef
and, as with the reef, the chamosite oolite part of the
rock has been completely oxidised to limonite.

The phosphatic nodules in Bed 4 yielded fragments of
species of <u>Prodeshayesites</u>, <u>Cheloniceras</u> and <u>Dufrenoyia</u>,
being part of the re-worked Lower Aptian fauna referred to
above. The absence of these nodules from the third
excavation and their wide spacing in the fourth explains
the difficulty experienced in the Hunstanton Borehole.
The large numbers of ammonite fragments derived from this
bed which occur scattered along the outer Carstone reef
suggest that elsewhere along their outcrop the fossiliferous
nodules are more densely packed than was seen in the
excavations. Larger rough-coated phosphatic nodules (up
to 0.12m across), with sandy cores and often with ooliths,
sand grains and pebbles stuck to their outer surfaces,
also occur in Bed 4, but these appear to be unfossiliferous.
Many appear to take the form of burrow fills.

Keeping's iron-grit nodules were not seen in any of the
excavations but Mr. LeStrange collected several nodules,
whose lithology closely fits Keeping's description, from an
exposure near the pier in the 1930s. These nodules, now in
the British Museum (Natural History), are composed of dark
brown sandy phosphatic ironstone, crowded with moulds of
tiny bivalves (e.g. BM Nos C 35512 and C 35238). The
original nodules were well-rounded and up to 0.20m across,
but have now been broken up to reveal the fauna. In
addition to the bivalves, fragments of coalified wood are
relatively common and a few ammonite fragments are present.
These latter have been described by Casey (1961, p.571) as
'Barremian ammonites of the genus <u>Paracrioceras</u> and as
being the same as the '<u>Hamites</u> or <u>Ancycloceras</u>' of Keeping.
The nodules were distinctly rare even when the base of the
Carstone was well exposed and, according to Mr. LeStrange,
occurred in small groups in a clay about 0.15 m below the
base of the Carstone (i.e. in Bed 3 of the excavation).

Bed 3 is clearly that recorded by Lamplugh and
previously taken to be the Snettisham Clay. The pebbles
and ooliths within this bed and within Bed 2 are identical

to those which made up a large part of the typical Carstone lithology. The junction of Beds 3 and 4 in the excavation was obscured by ferruginous seepages and by oxidation, and in the Hunstanton Borehole's cores by intense burrowing. However, Beds 2 and 3 appeared, in both sections, to pass up by addition of pebbles and sand into Beds 4 and 5. The only clear sedimentary break in both the excavation and the borehole section was at the base of Bed 2. It would be possible therefore, on lithological grounds alone, to consider Beds 2 and 3 as part of the Carstone. The increase in pebble concentration and the sudden appearance of the re-worked Lower Aptian fauna in Bed 4 suggest a marked increase in the energy of the sedimentary environment at the base of Bed 4, probably accompanied by a much wider area of sediment source. The presence of a Barremian fauna in the iron-grit nodules is not in itself conclusive proof of the age of Bed 3 since the nodules are themselves probably re-worked. The Carstone is considered at the present time, on indirect evidence, to be Lower Albian in age and it would be curious, assuming Beds 2 and 3 were taken as part of the Carstone, if a re-worked Barremian fauna were to appear before a re-washed Lower Aptian fauna in beds of Albian age. The simplest interpretation, until more palaeontological evidence is available, would be to assume that Beds 2 and 3 are part of a separate formation, different from both the Carstone above and Bed 1 below, of Barremian or younger age.

At the base of Bed 2 there is a marked lithological change; in the beach excavation burrow fills of Carstone lithology sand extend down from the base of Bed 2 in much the same way that, southwards from Hunstanton (where the Carstone rests on progressively lower parts of the Lower Cretaceous) burrow fills of Carstone penetrate the Snettisham Clay at Leziate (TF 684 194) and the Sandringham Sands at Blackborough End (TF 677 144). In the Hunstanton Borehole, where an almost identical sequence of

lithologies was recorded, this junction appeared to channel
down into the underlying sands (Fig. 2). The sandy
nodules contain traces of bedding and burrow mottling and
appear to have accreted <u>in situ</u> around burrows and to have
preserved part of the indigenous fauna of the sands.
Unfortunately most of this fauna is indeterminate but it
does include an ammonite fragment which can be matched with
the <u>Paracrioceras</u> of the iron-grit nodules both in form and
in mode of preservation. Indeed the whole fauna and
lithology of the nodules from Bed 1 is very similar to that
of the iron-grit nodules, except that the latter are more
fossiliferous, more densely cemented and more finely sandy.

In the Hunstanton Borehole section the sands corre-
lated with Bed 1 form part of a complex sequence of sands,
clays and pebbly oolitic clays which can be lithologically
matched with the Roach of Lincolnshire. In the borehole
this sequence overlies, without obvious disconformity, clay
of similar lithology to that of the Snettisham Clay of the
Heacham - Snettisham area, which latter has yielded a fauna
of Lower Barremian crioceratid ammonites (Spath 1924, p.79).
It seems likely therefore that Bed 1 will prove to be
Middle or Upper Barremian in age.

The clays referred to by Whitaker and Jukes-Browne
(1899, p.12) found in sinking piles for the pier probably
also belong with the Roach. The true Snettisham Clay
probably crops out some way below the lowest tide mark and
has never been seen at Hunstanton. The Roach clays are cut
out southwards from Hunstanton by the Carstone overstep and,
with one possible small area of exception in the valley of
the Barrett Ringstead Stream (TF 679 393), do not crop out
in Norfolk.

Acknowledgements
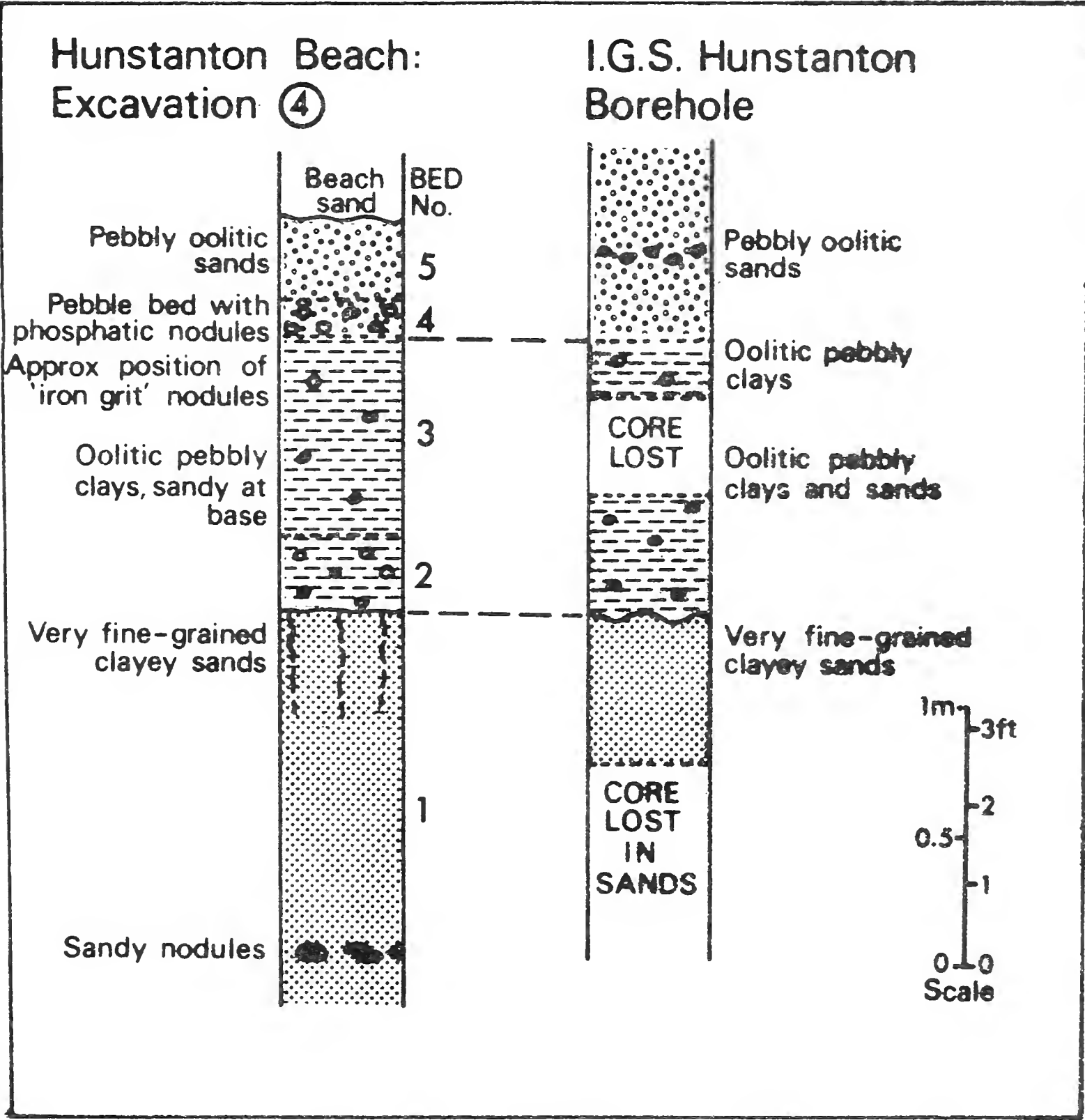
Fig. 2. Lithological comparison between the beach section and the Hunstanton Borehole.

his local knowledge of Hunstanton beach was essential to
their success. In addition, the preparation of this
account has been made considerably less difficult, and less
ambiguous, by the incorporation of his personal
observations on exposures long since covered up by the
drifting beach sands.

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EARTH SCIENCE TEACHING AT THE OPEN UNIVERSITY

R. C. L. WILSON*

   In the middle of 1969 a small group of Open University
academics and administrators had to decide how to prepare
degree courses which could be taken by students working
largely independently at home. In science, nine faculty
members had the additional problem of how to provide
adequate practical science experience to students working
at home. In addition the two geologists amongst them had
to begin to think how to teach Earth Science 'at a
distance', and in particular how to provide adequate field
and practical experience for students wishing to study in
the Earth Science area.

   In less than two years the system of teaching was
devised, and if success can be judged by the Open
University's current enrolment of 42,000, sales of its
materials and their use in other educational establishments,
and numerous visitors to the campus, then we have been
successful. Our system works well, but it is by no means
perfect, and so it is constantly evolving, and we hope
improving.

   How was the problem of teaching at a distance overcome?
To many people, television would appear to be the medium
for such instruction, but in reality the amount of TV time
(less than 10 per cent of the student's workload) makes it
almost useless on its own. The success of our system is
due to the degree of integration achieved between all the
components of our courses. Rather than itemise these, an
example will demonstrate the concept much better. Part of
the Second Level Geology course, which students take after
they have finished the Foundation Course (of which more
later) involves the study of geological maps.

   The 'core' of all Open University courses is the unit

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text, which in the case of the map course is entitled
'Field Relations'. These texts are designed for students
working alone, so they are 'structured' accordingly. At
the beginning of each text the <u>performance objectives</u> of
that part of the course are stated, spelling out to the
student what he should be able to do after completing his
work that he could not do before (Fig. 1).

Objectives

When you have finished this Block, you should be able to:

1   Define correctly, or recognize the best definitions of, or distinguish between
    true and false statements involving terms, principles, laws and concepts in the
    third column of Table A.

2   Demonstrate a working knowledge of map scales, orientation, co-ordinates,
    contours, dip, strike, and outcrop patterns by successfully carrying out
    exercises and calculations on geological maps.

3   Construct a topographic and geological section and correctly identify features
    depicted on it.

4   Identify correctly unconformities on a map, and distinguish them from other
    types of geological boundaries.

5   Given d..   ' · geological stru·   ·rties of rocks ·

Fig. 1.   An example of some of the performance objectives
          for the <u>Field Relations</u> section of the Second
          Level Geology course.

Next, the concepts and terms in the text with which the
student should be familiar are listed in 'Table A' (Fig.2),
and this table is always referred to in the list of
objectives. Then follows the main text. Figures 3 - 7
show examples from the 'Field Relations' **which** teach
<u>contours</u>. The section starts off with a **stu**dy comment
(Fig. 3), which states the relevant objec**tives** in a more
conversational way. The section on contours **uses** three
dimensional cut-out models, which students cons**truct** and
use in conjunction with the text as instructed (**Fig.** 4).
So this is an example of a simple visual aid linked **to** a
written text. Similarly, the written text can be **linked**
to an item of TV teaching. Figure 5 shows another part
of 'Field Relations', which was taught in detail on
television with aid of a three dimensional model based on

List of Terms, Concepts and Principles used in Block 2

Taken as prerequisites					
Assumed from general knowledge (GK) or from S100 (Unit No.)		Defined in previous S23 – Blocks	Block	Developed in this Block	Page No.
FR 1 map scale National Grid grid reference topographic map geological map Phanerozoic	GK GK GK GK GK 26	Cambrian Ordovician, etc.	3	grid reference solid and drift maps geological symbols	10 11 11
FR 2 topographic contour topographic section or profile	GK GK			geological structure outcrop pattern dip structure contour strike true dip apparent dip 'V's	13 13 13 15 15 16 16

Fig. 2. Part of the 'Table A' of the <u>Field Relations</u> section of the Geology course, which indicates to students the terms, etc. they will need to know before reading the text, and the terms, etc. with which they should be familiar after completing it.

FR 2   Plotting Three–dimensional Surfaces in Two Dimensions

Study Comment

This Section introduces the concept of geological maps as two-dimensional representations of three-dimensional topographic and geological surfaces. The intersection of these two surfaces produces a geological outcrop, the pattern of which indicates the form of the geological surface. This is generally described as a geological structure. By the end of this Section you should be able to recognize the basic patterns produced by simple planar geological structures, namely horizontal and dipping strata. The method of drawing topographic and geological sections is introduced.

2.1   Introduction

You are probably used to using maps as an aid in travelling from place to place —on footpaths or roads. But many road maps leave out, or greatly simplify, the topography of the areas they depict, so you may not be too familiar with reading maps which show contours. *All types of maps depict a three-dimen~·   ·   ·~ation in two dimensions o~   ~~er.* Photographs d~ ··

Fig. 3.   An example of a study comment at the beginning of a section of the <u>Field Relations text</u>, the purpose of which is to remind students of the performance objectives of this section.

R. C. L. Wilson

2.3 Contours

Contour lines join points of equal elevation on a surface

If you place a pad of ruled paper against a book in the manner shown in Figure 5, the lines on it are topographic contour lines. Or take model 1 : on the side of it are marked centimetre intervals—these give the 'altitude' of different parts of the model (Fig. 6a). When these are projected on to the sloping surface of the model, the lines are the *topographic contours* for that slope. On the other side of the model (Fig. 6b) a bed of sandstone is marked, having the same inclination
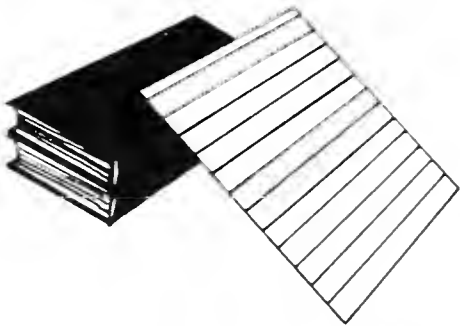
Figure 5 Ruled pad of paper resting against a pile of books: lines represent contours.
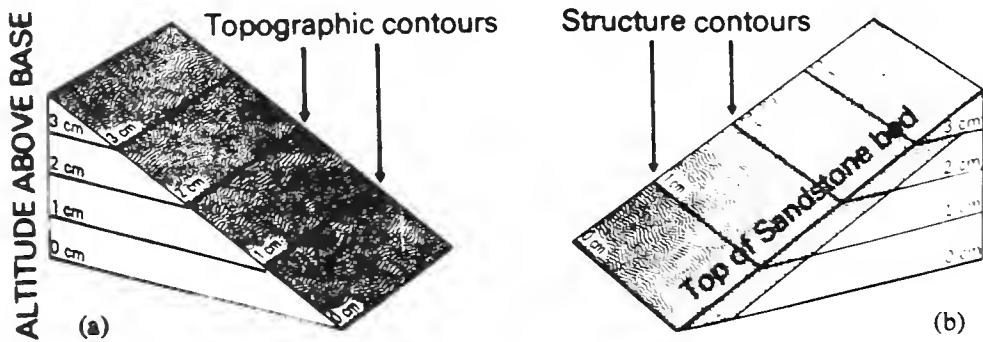
Figure 6 (a) Model 1, illustrating topographic contours on an inclined planar surface. (b) Model 1, illustrating structure contours on the top of an inclined bed of sandstone.

as the 'topographic surface' of the model—so the whole of the top surface is the outcrop. And the contours are also *structure contours*—they join points of equal elevation on the upper surface of the sandstone. These contours can be projected on to a planar surface, as shown in Figure 7a, using models 1 and 2. Figure 7b shows the *dip* and *strike* directions marked on both models—mark them in on your models. *The strike is the direction, with respect to true north, of a horizontal line in the plane of an inclined bed. It is perpendicular to the direction of the dip.*

structure contour

strike

(a)   (b)
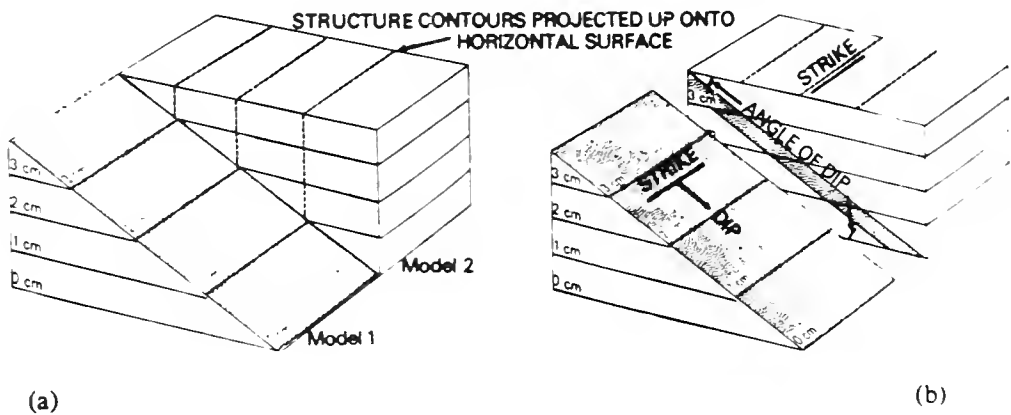
Figure 7 (a) Projection of contours onto a planar surface. (b) Dip and strike directions marked on Models 1 and 2.

Fig. 4. An example of instructional text linked to simple three dimensional models constructed by students.

2.5 Using contour maps

You are probably already familiar with using topographic contour maps. As a check try Question 5.

Figure 10 *Contour map for use with Question 5.*

100 feet   Contours in feet

Question 5 Examine the contour map shown in Figure 10 and answer the following:
(a) In which direction is the river flowing?
(b) Which is steeper, slope A or slope B?
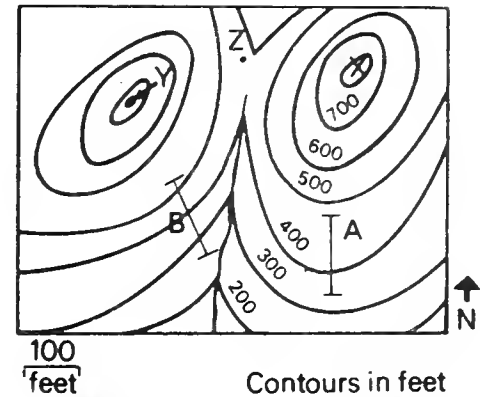(c) Which is the highest point—X, Y or Z?

(a) River flows to the south.
(b) B is steeper.
(c) Y (just over 900 feet).
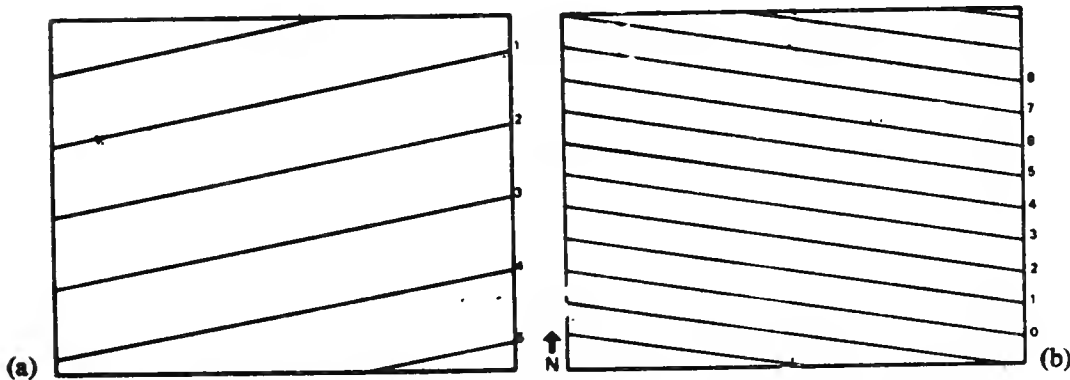
Figure 11 *Structure contour maps for use with Question 6 (inter als of 100 feet).*

Question 6 Examine Figure 11 which shows two simple structure contour maps of a geological surface.
(i) Which map shows strata dipping in a northerly direction?
(ii) Is the surface dipping more steeply in map (a) or map (b)?

(i) Map (a) shows surface inclined to the north.
(ii) Map (b) shows surface inclined more steeply than in map (a).

Question 9 Let us assume that the structure contours in Figure 11b are of a coal seam underlying the land surface shown in Figure 10. Superimpose Figure 10 on Figure 11b by making a tracing, and draw in the outcrop pattern of the coal seam.

The correct pattern is shown in Figure 14. Note again the 'V' pattern—illustrating the law of the 'Vs'—the 'V' points in the direction of dip.

Fig. 5.

(Figure continued overleaf)

While the law of 'Vs' holds in most cases for dipping beds, there are two important exceptions when it does not hold: *horizontal strata*, and strata which dip *downstream* at a *lower* angle than the gradient of the stream will 'V' *upstream*.

Contours in feet
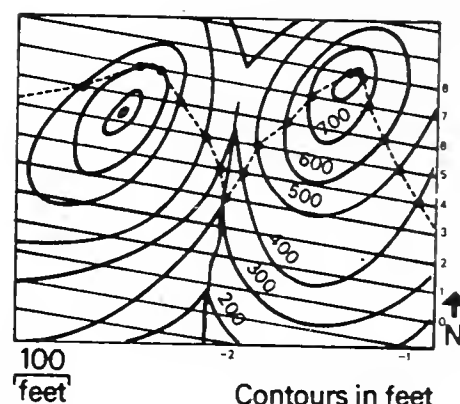
*Figure* 14　*Solution to Question 9: Outcrop pattern produced from data in Figures 11b and 10.*

Fig. 5.　Parts of the <u>Field Relations</u> text showing how it is made 'student active'. Figures 10 and 11 form the basis for a model (Figure 6 opposite) used on a TV programme.

figure 10 and 11b of the text (see Fig. 6). This example from the text also shows how the written word is made 'student-active'; questions are posed in the text for students to work out, and answers are then given in the margin. This is a simple kind of programming, but sometimes other types of questions are used where answers are given at the end of the text, or self-assessment questions are collected together at the end of the text for the student to check whether he had achieved the objectives stated. 'Field Relations' also uses a collection of five geological survey maps which students purchase; the main text refers to these maps many times and they are also used for assessment purposes. None of the individual teaching methods used is new, but their combination and integration have produced a different kind of teaching method designed specifically for the independent learner.

When students have completed the core of the course, they are assessed either by tutor marked assignments (TMA) or computer marked assignments (CMA). TMAs in the case

Fig. 6.　TV demonstration used to teach the concepts of <u>topographic</u> and <u>structure</u> contours.
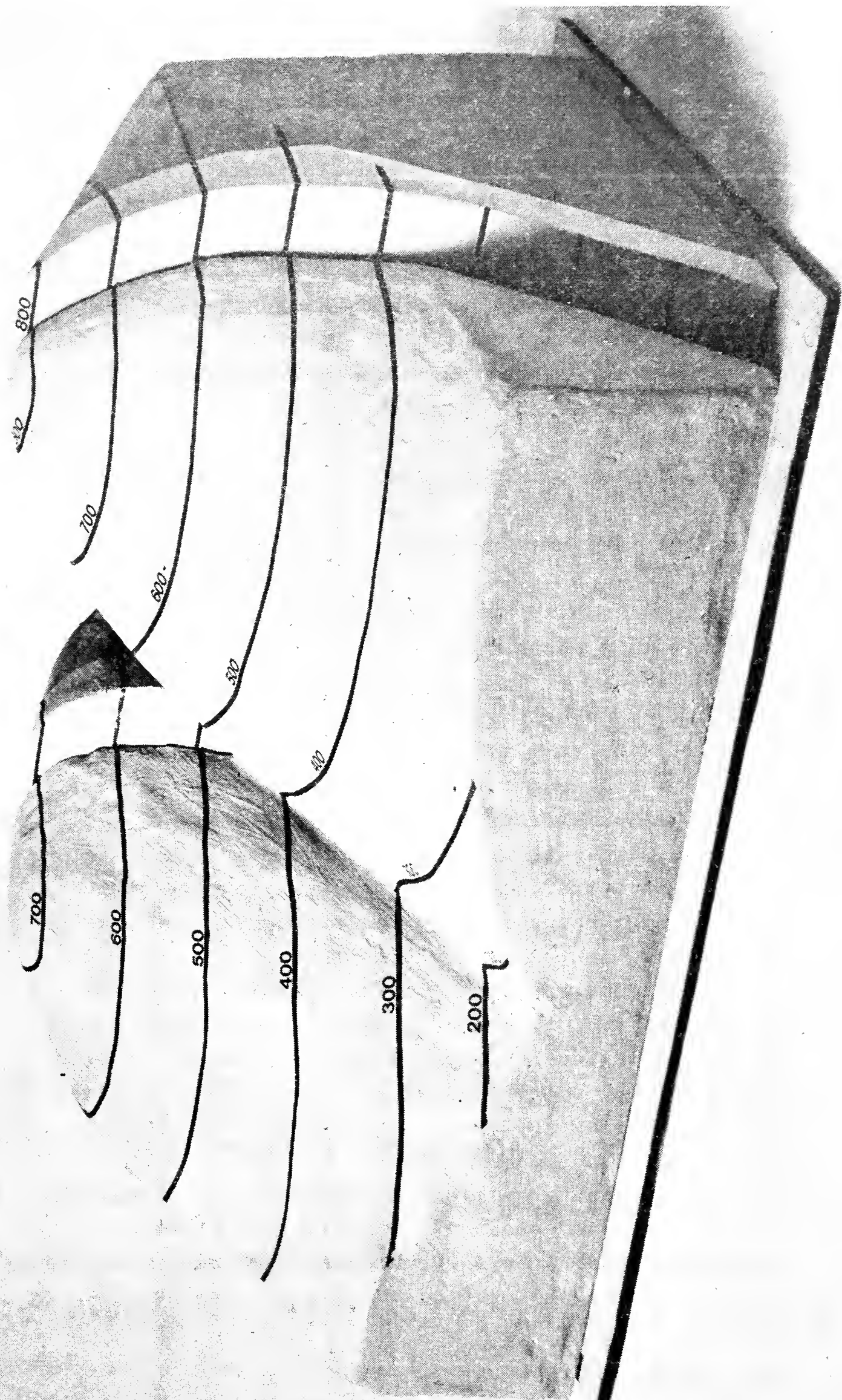
of the map course involved section drawing, or identifying
given geological structures, or writing geological
histories from map evidence. These assignments are marked
by part-time tutors, who meet students at local study
centres to discuss various aspects of the course and the
assignments. CMAs involve objective tests, with a student
choosing his answer from a number of alternatives (Fig. 7),
pencilling out the appropriate letter, and later transferring
all his answers to a sheet which is sent off to the Open
University headquarters to be marked by a computer - at the
rate of 4,000 an hour! CMAs have proved to provide a
considerable learning incentive to students, as when working
through them. they are forced to consider very carefully
whether or not they have grasped a particular part of the
course.

An introduction to mineralogy and petrology is given
using another unit text, entitled 'Earth Materials', and
also using the bulk of the home kit (Fig. 8) which consists
of a McArthur petrological microscope especially designed
for the course, 25 rock specimens and 23 thin sections, 7
minerals, 7 fossils and other items including an acetate
peel kit and materials for demonstrating aspects of
structural geology. It is impossible to read the 'Earth
Materials' text satisfactorily without having specimens to
hand and the microscope set up, for throughout students
have to complete tables summarising the properties of the
specimens and thin sections. During the eleven weeks'
duration of the Geology course, students meet part time
tutorial staff at local study centres to discuss problems
encountered during their studies. Students gain experience
of field work during a week's summer school, which is at
present based at the Department of Earth Sciences at the
University of Leeds. The programme alternates between
field and laboratory sessions, each laboratory session
providing the opportunity for students to go over the field
work they have done the previous day, or to revise any

Block Z (See Map 2)

Q.Z1 Which lithological unit rests unconformably on older strata? (Pencil out A, B, C, D, E, F or G)

Q.Z2 In which direction does the unit identified in Q.Z1 overstep?

KEY A : north
     B : south
     C : east
     D : west
     'd' : don't know

Q.Z3 What is the approximate angle of discordance of the unconformity in a north-south direction?

KEY A : 0°
     B : 4°
     C : 8°
     D : 12°
     E : 16°
     'd' : don't know

Q.Z4 What is the approximate angle of discordance of the unconformity in an east-west direction?

KEY A : 0°
     B : 4°
     C : 8°
     D : 12°
     E : 16°

Q.Z5 Which of the following statements is correct?

KEY A : Only the beds above the unconformity V upstream.
     B : All the beds V downstream.
     C : The beds below the unconformity V upstream.
     D : All the beds V u---- ---.

Q.Z6 What is the minimum thickness of the beds above the unconformity?

KEY A : 100 feet   E : 500 feet
     B : 200 feet   F : 600 feet
     C : 300 feet   G : 700 feet
     D : 400 feet

In comment row 2 of. Block Z indicate, by pencilling out the appropriate cell from the key below, how enjoyable were the questions in Blocks X, Y and Z in the sense that you experienced pleasure in doing them.

KEY a : very enjoyable
     b : fairly enjoyable
     c : not very enjoyable
     d : not at all enjoyable

Likewise, in comment row 3, say how difficult these same questions were.

KEY a : very difficult
     b : fairly difficult
     c : not very difficult
   d : not at all difficult

This block carries 15 per cent of the marks for this assignment.

Block Z cells for Q.Z1–Z6

Fig. 7.   An example of an objective test used in conjunction with a simple geological map used for a Computer Marked Assignment (CMA) for the Geology course.

aspect of the course that they wish. A student summer school book forms a detailed guide to the field work they undertake, thus freeing tutors to deal with individual student problems as they arise.
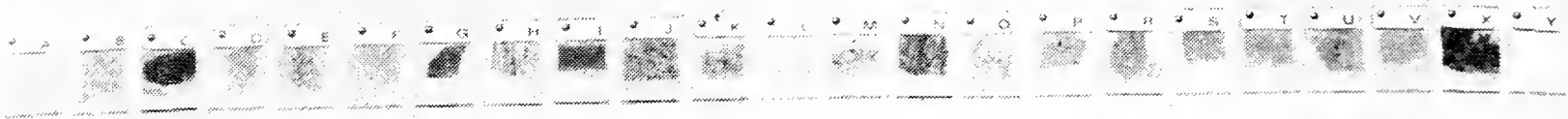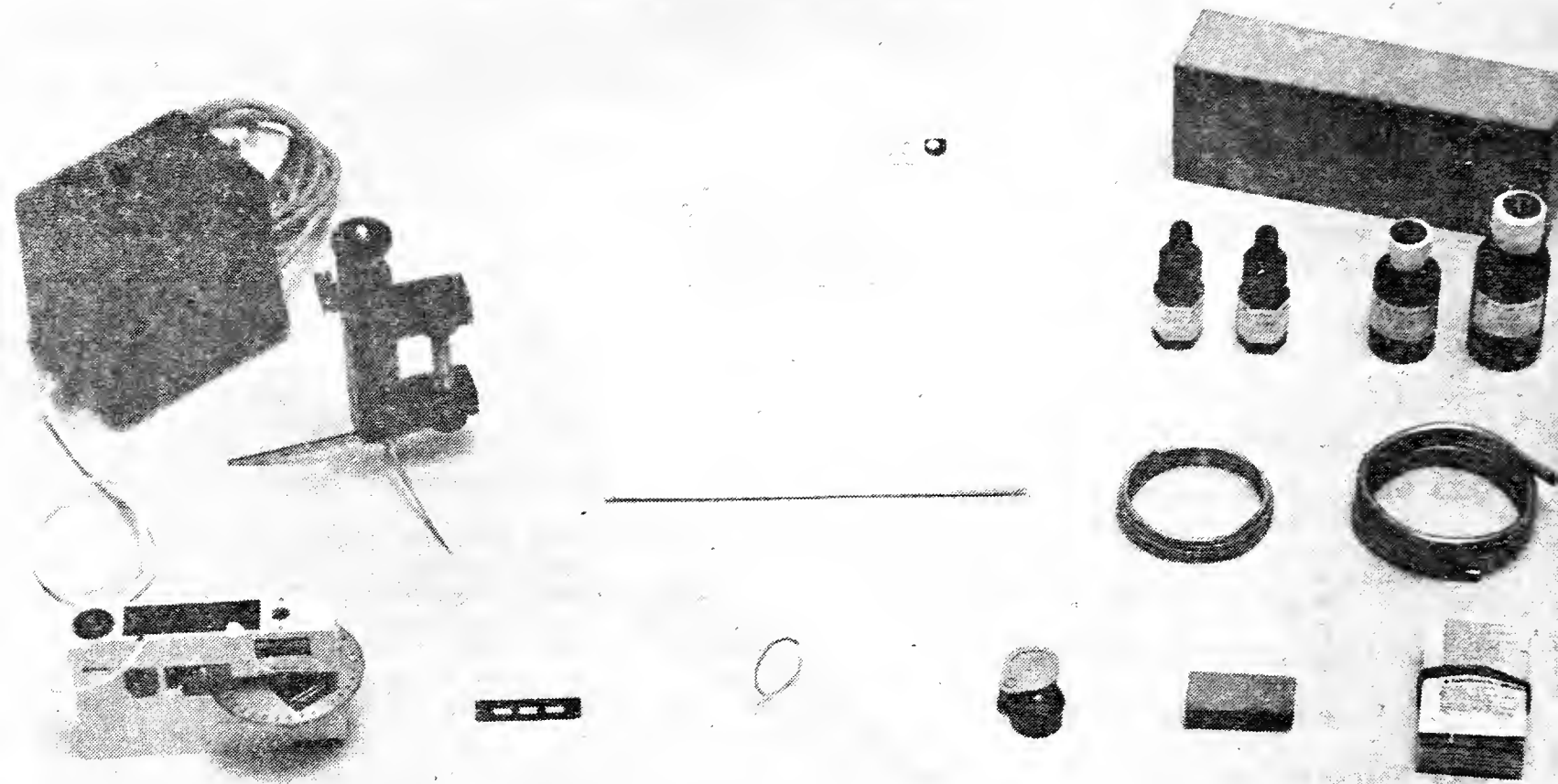
At the end of each course, students sit a final examination, which carries equal weight with their continuous assessment grades. A summer school assessment is used to arbitrate on borderline pass-fail and pass-distinction cases.

Table 1 summarises the components already discussed which make up a <u>course unit</u>. Thirty four course units make up a credit course, and six credits (of which two must be at foundation level) are needed for a student to gain an ordinary B.A. degree, and eight credits (of which two must be of foundation level and at least two at third level or higher) to give an honours B.A. degree. Foundation courses are broad interdisciplinary courses available in the faculties of Humanities, Social Science, Maths, Sciences and Technology. The Earth Science component of the Foundation Course in Science deals with large scale geology, rather than 'pigeon hole' geology. Material is biased towards geophysics, providing the opportunity to teach physical concepts such as reflection and refraction, rigidity and magnetism in the context of their relevance to the study of the Earth. The title of the units are 'The Earth, its shape, internal structure and composition', 'The Earth's magnetic field', 'Major features of the Earth's surface', 'Continental movement, Sea-floor spreading and Plate Tectonics', 'Earth History 1', and 'Earth History 11'. Once students have successfully

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Fig. 8.   The home kit for the Geology Course. Top left: McArthur petrological microscope, tripod and transformer; top centre: instructions and roll of acetate peel; top right: large sponge coils of solder, plasticene and sliced telephone directory used for experiments associated with structural geology; the bottles contain acetic and amyl acetate for making acetate peels with the acetate sheet. Lower half of photography: thin sections, rocks fossils and minerals. The kit is packaged in specially moulded polystyrene containers and loaned to students for the duration of the course.

TABLE 1 - Components of an average Course Unit in
          Earth Science

Component	Study time (hours)	Description
CORRESPONDENCE TEXT	10	Specially written and structured text, containing behavioural objectives, table of scientific terms, etc., and self assessment material integrated with home kit materials.
SET READING	1.0	Reading parts of 'set book', which in some cases may have been specially written for the course (e.g. 'Understanding the Earth', set for all Earth Science courses).
HOME PRACTICAL WORK		Collection of 25 rocks, 7 minerals, 23 thin sections and 6 fossils, a petrological microscope, acetate peel materials and demonstration materials for structural geology. The kit is constantly referred to in correspondence texts.
COMPUTER-MARKED TEST (Weekly)	1.0	Objective tests; answers given by pencilling out items on sheet read by computer.
TUTOR MARKED TEST (spread over several weeks)	4.0	Subjectively marked; essays, short-answer questions, accounts of experiments.
TV PROGRAMME	0.5	Demonstration of conceptually difficult items or laboratory demonstrations.
RADIO PROGRAMME	0.5	Teaching material, or material showing history or social relevance of science.
BROADCAST NOTES	-	Notes containing instructions on tasks which should have been completed before the broadcasts, and summaries of the programme.

completed one foundation course they may go on to level
two courses, a number of which are available in the
geology area (Table 2). Students must combine a one
third credit course with a one sixth credit course to
give an overall half credit. This system ensures that
at least some interdisciplinary approach is maintained
during second level studies.

TABLE 2 - A summary of second level geology courses

Course title	Credit rating	Content
GEOLOGY	1/3	The aims of this course are to train students to approach objectively the identification of minerals and rocks and understand their genesis; to interpret major structural and geomorphological features and be able to deduce the processes involved in their formation; and to understand the principles of stratigraphy and palaeontology.
		There will be considerable emphasis on practical work throughout the course, and the home experiment kit will include a petrographic microscope, thin sections of rocks and a collection of specimens.
THE EARTH'S PHYSICAL RESOURCES	1/3	In this course, attention will be focused on the occurrence, location, processing and utilization of natural resources, ranging from metallic ores through the mineral fuels, oil, coal, natural gas and fissile materials to materials used in construction and industrial processes such as building stone, road metals, cement, metallurgical fluxes and fertilizers. Another title for this course could be 'geology in the service of man'. /continued overleaf

GEOCHEMISTRY	1/6	In this short course, the main emphasis will be on the methods by which geochemists select and analyse accessible Earth materials, the relationships between the chemical composition and the structure of rocks and minerals, the chemical aspects of the Earth's structural evolution, geochemical reactions and cycles, and the practical applications of geochemistry.
GEOPHYSICS	1/6	In this course, selected topics will be examined to illustrate the contribution of physics to our knowledge of the Earth. The emphasis will be on basic physics as applied to the Earth, rather than on the use of physical techniques to extend geological study.
ENVIRONMENT	1/6	This short interdisciplinary course will show how physical and biological processes influence the distribution of organisms and geomorphological or sedimentological features of natural environments. Particular attention will be given to coastal, river, lake and glacial environments, as they are well represented in the British Isles. The course is also intended to stimulate appreciation of the environment through the greater understanding of processes occurring in it, with a view to reconciling exploitation with preservation.

In this short article it is difficult to cover adequately all aspects of the Open University teaching system, but, one filal aspect that must be mentioned is the evaluation system. Feedback of all kinds reaches the course team (the team that has prepared all the course

materials). The assessment system is one kind of feedback, the summer schools another, the part-time tutors yet another. In addition, the reaction of academics in other departments is sought concerning the courses before they actually reach students, as they are evaluated before they are finally printed. In addition much time is spent in trying to isolate conceptually difficult parts of the course, and those parts of the course which have been badly taught. In the case of the Geology course this was accomplished by sending a specially designed questionnaire and log sheet to a randomly selected sample of students. Collation of the answers received provided a very rapid feedback and has enabled the course team to give a certain amount of guidance to tutors in the first year of the courses' operation. The evaluation of the course is now continuing with an in depth study of students understanding of some of the key concepts introduced in the course. In this way we hope that the Open University will live up to its name in _every_ sense of the word, having an open admissions policy requiring no formal qualifications, open as to teaching methods, open as to new ideas, and above all being open to criticism.

The first event of the year was the Annual General
Meeting for 1971, held on the 6th of January, and followed
by a showing of members' slides.

There have been five lecture meetings during the year;
a sixth was postponed due to the emergency regulations
imposed during the national power cut in February. The
meetings were: January, Dr. R. G. Bromley on 'The Dryas';
February, postponed; March, Mr. P. G. Cambridge on
'Fossils of the Norwich Crag'; April, joint meeting with
the Norwich Astronomical Society, I. O. Evans on 'The Earth
- this surprising world'; October, Dr. R. G. West on 'A
state of confusion in Norfolk Pleistocene stratigraphy';
November, Dr. F. J. Vine on 'Geology of the Deep Ocean Floor'.

The Committee has met three times, on the 11th April,
28th September and 23rd November.

At the Annual General Meeting I indicated that I did
not wish to continue as Secretary after the end of 1972, but
remarked that this should not be taken as reflecting any
change in my attitude to the Society. Its Secretary, whoever
he may be, quite naturally exerts some influence over the
direction of the Society, so a periodic change is desirable
to prevent too much bias one way or another. In my tenure
of office the bias has been towards the museum and the
lecture programme has been somewhat influenced by my
personal tastes. The Society is now, I believe, ready for
an expansion in membership, and some changes in emphasis,
and I am confident that Dr. C. J. Aslin will as Secretary
provide this. The last two meetings, held in the Castle
schoolroom, have been so well attended that better
accommodation is required; the four remaining meetings of
the Winter programme are to be held at U.E.A., which offers
better facilities.

I hope members will actively support the new Secretary
and Committee under the new arrangements.

December 1972   Brian McWilliams

CONTENTS   Page

The Geological Society of Norfolk exists to promote
the study and knowledge of geology, particularly in East
Anglia, and holds monthly meetings throughout the year.

Visitors are welcome to attend the meetings and may
apply for election to the Society.   For further details
write to the Secretary: Dr. C. J. Aslin, The University
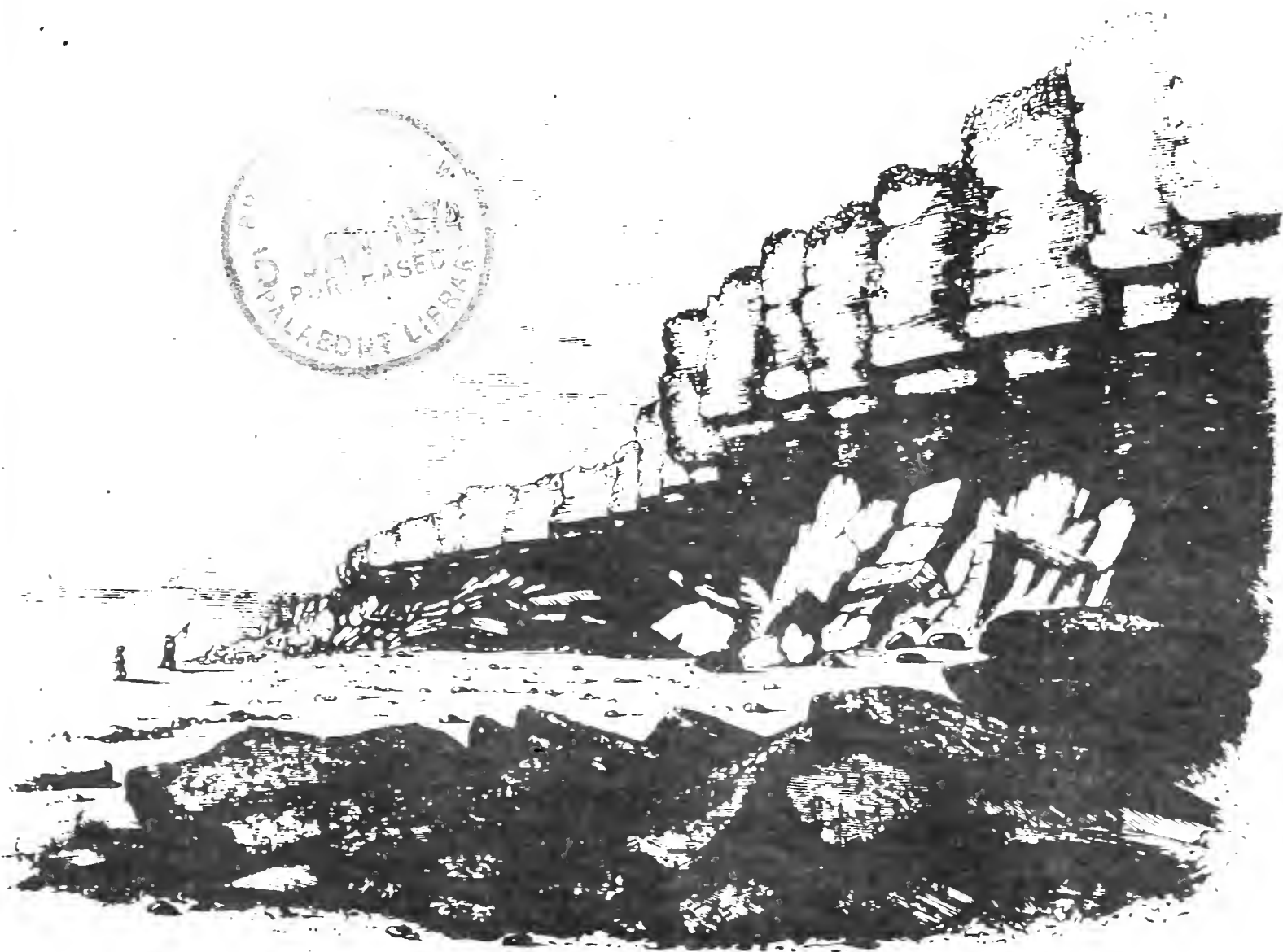Library, University of East Anglia, NORWICH NOR 88C.

Copies of this Bulletin may be obtained, 60p (post
free), from the Secretary at the address given above;   it
is issued free to members.

Also available, at 75p (post free), is "The Geology
of Norfolk", a 108 page book describing the geology of the
county, reprinted by the Society in 1970;   members of the
Society may buy one copy only at 40p.

BULLETIN OF THE GEOLOGICAL SOCIETY OF NORFOLK

No. 24

CONTENTS INCLUDE:

EDITORIAL

The autumn edition sees the publication of two papers
of great interest based on local fieldwork.   Eaton caves
provided the basis for interdisciplinary work by Messrs.
Hornby, Goff and Goldsmith, while Dr. Randall throws new
light on the Suffolk coast.   There is also a report on a
field meeting at Sheringham held last summer.   Much
independent fieldwork is being done quietly around East
Anglia by a growing body of interested amateurs and
professionals.   When any worthwhile work has been completed,
it is well worth writing it up for publication, and brevity
need not be a drawback;   in fact having a series of articles
of varying length helps an editor.

Bulletin No. 25 will be issued in April 1974.   Contri-
butions should be sent to me as soon as possible, and no
later than December 31, 1973.

Will contributors please note that manuscripts are
acceptable in legible handwriting, although typewritten copy
is preferred.   In either case it would be a great help if
details of capitalisation, underlining, punctuation, etc.,
in the headings and references (particularly) could conform
strictly to those used in the Bulletin.   Otherwise
publication may be delayed.   ·

Illustrations intended for reproduction without re-
drawing should be executed in thin, dense, black ink line.
Thick lines, close stipple, or patches of black are not
acceptable, as these tend to spread in the printing
process employed.   Original illustrations should, before
reproduction, fit into an area of 225 mm by 175 mm;   full
use should be made of the second (horizontal) dimension,
which corresponds to the width of print on the page, but
the first (vertical) dimension is an upper limit only.
All measurements in metric units, please.   R.J.S.

2

EATON CHALK PIT - SITE OF SPECIAL SCIENTIFIC INTEREST

R. J. HORNBY*, J. G. GOLDSMITH/ and J. C. GOFF[x]

What is an SSSI?

Only a small fraction of all the land showing important natural features is, or ever can be, protected by means of nature reserves. There is therefore, a need to protect areas which are not established as nature reserves but which are nevertheless of interest on account of their flora, fauna, geology or physiographical features. In order to help prevent such areas from being unwittingly damaged or destroyed by development, the Nature Conservancy designates Sites of Special Scientific Interest (SSSIs) and lists them in schedules covering each local planning authority area.   These schedules are distributed to the planning authorities and to many other bodies whose activities might in any way threaten the listed sites. SSSIs are carefully selected in order to safeguard localities for rare species or communities, and they include the whole range of semi-natural habitat types. Other sites are scheduled not so much to safeguard a valuable habitat for wildlife but to help ensure that exposures of particular geological significance continue to be available for scientific investigation. The protection of geological SSSIs, which are often quite small in area, usually operates through the planning authority who consult the Nature Conservancy in the event of development proposals likely to affect the site.

Eaton Chalk Pit is one such site. The designation of the northern side of the pit as an SSSI in October 1968 was based primarily on the status of the site as the type locality for the Eaton Chalk.

* Assistant Regional Officer, The Nature Conservancy,
  60, Bracondale, NORWICH, NOR 58B.
/ Castle Museum, NORWICH, NOR 65B.
x Owl's Hatch, SALHOUSE.

History of the Pit

It has not been possible to determine the date when
chalk was first mined at Eaton, but the pit was known to
have approximately its present dimensions at the turn of
the century, and as all the chalk was dug by hand it
indicates an origin probably in the early part of the
nineteenth century. The chalk was used for the manufacture
of lime and virtually all of it would have been roasted in
kilns on the site. Two such lime kilns are known to have
been in operation in the pit. The smallest, and oldest,
of these still survives in reasonable condition to this
day, but the other one, which was of German design and was
constructed in 1889, has been filled in. The kilns were
kept burning continuously and it is reputed that the only
time they went out during the long operational life of the
pit was in the flood of 1911. The fires were not finally
extinguished until 1936 when the business closed down.

The chalk, which was mined solely with picks, was
carried to the kilns along an often precarious system of
planks, using heavy wooden wheelbarrows. The roasted chalk
was subsequently carried manually up a flight of steps
from the kilns for loading onto carts. It was sold by the
cart-load or 'chaldron', which was just less than a ton.

Although the pit itself covers approximately 1 hectare,
the normal method of operation during this century, and
probably for much of the last century, was by digging a
series of tunnels. There are believed to have been at
least eight of these tunnels radiating outwards from the
pit; three of them running east-wards under Donkey Lane
and the remainder running northwards or westwards. The
chalk was mined from tunnels in order to avoid the problem
of disposal of the overlying sand and gravel. Some of the
tunnels were of considerable size, reputedly large enough
to take a double-decker bus! They remained open until
1944 when the army sealed them off. The army's attempt to
block the entrances by blowing them up with explosives

proved utterly abortive, but the job was completed by
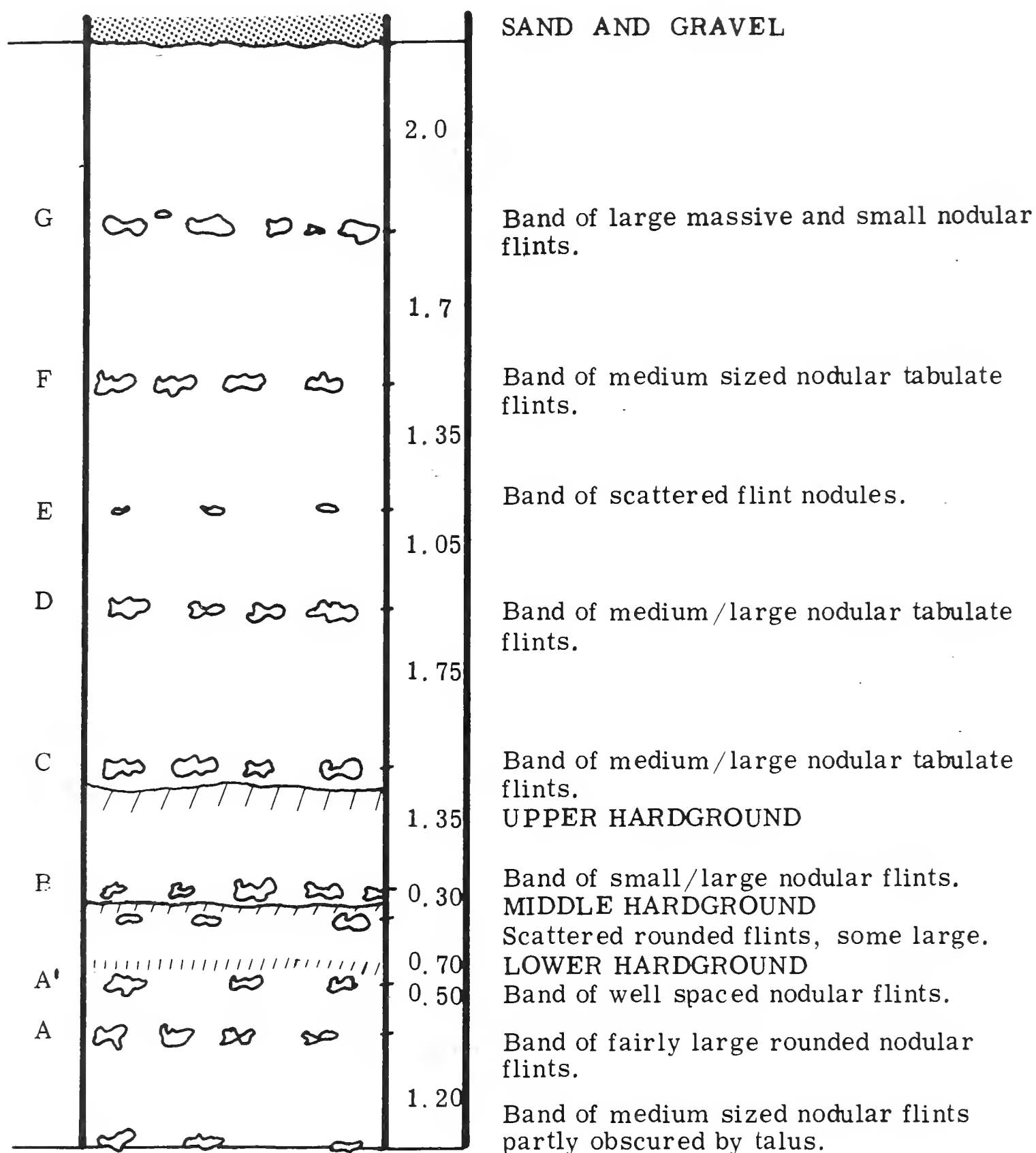bulldozing material over the entrances from the top.

All but one of the tunnel entrances remained
permanently sealed off but during the harsh winter and
floods of 1947 part of the cliff face fell away, re-
exposing a hole which formed a joint entrance to two
separate tunnels. Although well concealed by vegetation,
these tunnels were accessible to both geologists and
bats until March 1969 when they were again blocked by
material bulldozed into the pit from above.

Geology (by J. C. GOFF)

Eaton Chalk is the second lowest of the six sub-
divisions of the zone of Belemnitella mucronata adopted
by Peake and Hancock (1961, p.314). The tunnels at
Eaton Chalk Pit provide the only permanent exposure of
Eaton Chalk at present available. It is also the second
deepest exposure in the B mucronata zone in the Norwich
area. No overlaps of the section with exposures known
to be in the lower part of the Weybourne Chalk have yet
been proved. Part of the section may correspond to a
temporary exposure seen during foundation work for the
University of East Anglia. The total thickness of the
section, from the top of the chalk above the tunnel
entrance to the lowest part inside the cave is 12 metres.
The details of the section are shown in Fig. 1.

The letters in the section refer to flint bands
described by Dr. M. R. Leeder. The fossils that he
collected from the section, now in Norwich Castle Museum,
are numbered according to this system.

The beds of hard chalk (hardgrounds) represent
periodic shallowing of the sea when bottom currents were
stronger and greater amounts of terrestrial sediment was
carried into the sea. These hardgrounds are typically
associated with a rich fossil fauna. The upper hardground
contains glauconitic material and is separated from below

SAND AND GRAVEL

G   Band of large massive and small nodular flints.

F   Band of medium sized nodular tabulate flints.

E   Band of scattered flint nodules.

D   Band of medium/large nodular tabulate flints.

C   Band of medium/large nodular tabulate flints.
         UPPER HARDGROUND

B   Band of small/large nodular flints.
         MIDDLE HARDGROUND
         Scattered rounded flints, some large.
A'   LOWER HARDGROUND
         Band of well spaced nodular flints.

A   Band of fairly large rounded nodular flints.

         Band of medium sized nodular flints partly obscured by talus.

2.0
1.7
1.35
1.05
1.75
1.35
0.30
0.70
0.50
1.20

The letters in the left hand column are those used by Dr. Leeder to locate
fossils.   The middle column gives the distances between the flint bands,
which total 12.0 metres.

FIG. 1   THE SECTION THROUGH THE CHALK AT EATON

by a prominent bedding plane with a hard calcitic top. The
hardground increases in hardness towards the top. The
middle hardground consists of an irregular 7 cm band of
hard yellow chalk. The lower one consists of yellow chalk
of variable hardness.

The details of the fauna of the section are as
follows:-

Brachiopods:

      Cretirhynchia lentiformis Woodward, var ✕ Leeder

      Cretirhynchia cf. norvicensis Pettitt

      Neolithyrina obesa Sahni

      Carneithyris spp.

      Kingena lima (Defrance)

      Neoliothyrina obesa and the Carneithyrid brachiopods
are only known to occur above flint band E. They do not
occur in exposed lower horizons in the B. mucronata zone.

Kingena lima is characteristic of flint bands E - F.
Its occurrence here is significant stratigraphically - the
species being restricted to well defined horizons in the
zone.

Cretirhynchia lentiformis occurs throughout the section
and is especially common near flint bands E - F and B - C.
A large sample of this species from Eaton was measured and
the average length/width ratio was found to be 1.05. All
other known species of Cretirhynchia from the zone have
length/width ratios of less than 1. Dr. Leeder defines the
range of the variant as being from the Lower Eaton Chalk to
the Middle Weybourne Chalk.

Cephalopods:

Belemnitella occurs throughout the section and is
particularly common between flint bands B - C in the upper
hardground. The majority of the specimens from Eaton are
waisted forms referable to Belemnitella langei with some
tapering forms referable to variants of Belemnitella
mucronata. This indicates a horizon high in the Eaton Chalk.

Echinoids:

Small bun-shaped <u>Galerites</u> occur in the upper hard-
ground along with a conical form of <u>Echinocorys</u>. <u>Echino-
corys</u> is common near flint band A1, and a flattish oval
form occurs near flint band B. There are several specimens
of <u>Galeola</u> in the Norwich Castle Museum from Eaton.
However these specimens may have been collected from long
tunnels which extend from the caves towards the North East.
Thus they may have been derived from a younger horizon than
is seen in the present section (the dip of the chalk brings
younger beds to the surface in an easterly direction). The
specimens are the types originally described by Brighton in
1939.

Other fossil groups:

Sponges and clumps of Serpulids occur in the upper
hardground. Of the bivalves, <u>Pycnodonte</u> <u>vesiculare</u> and
<u>Spondylus</u> spp. are sparingly common.

<u>Bats</u>

Although the geological significance of the chalk was
the main reason for the area being designated an SSSI, the
presence of hibernating bats in the tunnels had also
influenced the decision. One of us (JGG), together with
J. Buckley, began visiting the tunnels at Eaton in 1964 in
order to examine the bats. Only one species, Daubenton's
bats (<u>Myotis</u> <u>daubentonii</u>) was ever recorded there, but
their presence in the tunnels had been known by at least
five other people during the preceding ten years. The
greatest number of individual bats recorded in these tunnels
was 30, but single figures were very much more normal.

In view of the decline in the populations of most
species of British bats (Stebbings 1965, 1967), and the
acute shortage of winter roosting caves in East Anglia, the
presence of bats in the tunnels at Eaton was regarded as a
highly significant factor. The majority of lime workings
which at one time had offered roosting sites for bats have
long been blocked off or have caved in and many other

possible sites are subject to human disturbance. It has
been shown by Stebbings (1966) that bats disturbed during
hibernation have a greatly reduced chance of surviving the
winter owing to the depletion of their food reserves by
unseasonal activity.

Present Condition of the Pit

The topography of the chalk pit has been subject to
considerable modification at various stages during its
history. Large volumes of overburden were shifted about
while the chalk was being mined, and later the near-vertical
walls of the pit were reduced to almost a 1 in 1 gradient
by the activities of the army during the war. In the early
1960s the main floor of the pit was raised about 6 metres
when it was used as a dump for large quantities of unwanted
soil and builders' rubble. The result of these activities
was that all the chalk faces were obscured apart from the
small surviving exposure by the entrance to the only
accessible tunnels.

Trees and scrub of various ages have become established
in the pit, creating a useful habitat for wildlife and an
unofficial adventure playground for local children. The
trees are mainly Birch, Ash, Oak and Sycamore, while Hawthorn,
Blackthorn, Privet and Elder are also abundant. The flora
of the site includes such species as Hoary Mullein (Verbascum
pulverulentum), Kidney Vetch (Anthyllis vulneraria), Spotted
Hawkweed (Hieracium maculatum) and Hybrid Medick (Medicago
falcata x sativa). The soil and rubble dumped in the floor
of the pit has also been colonised by an interesting mixture
of vegetation which includes much Fennel (Foeniculum
vulgare).

The Re-opening of the Tunnels

As has already been mentioned, the last of the tunnels
were blocked off in March 1969, after which only about 1
metre at the top of the chalk was accessible. The SSSI was
therefore hardly justifying its status and it was clear
that the possibility of re-opening one of the tunnels would

have to be investigated. A further factor in the decision
to go ahead with the re-opening of a tunnel was that R. E.
Stebbings was at the time seeking suitable sites in East
Anglia for the furtherance of his studies into the ecology
of bats. He particularly wanted to find caves in which
human access could be controlled so that disturbance to the
bats could be kept to a minimum. It was decided that, if
at all possible, an attempt should be made to re-open the
tunnels which had been sealed off in 1969. The reasons for
this choice were: (a) two tunnels could be opened by
clearing only one entrance, (b) one of us had known them
while they were open and knew in which direction the digging
would have to proceed, and (c) there was no doubt about the
suitability of the tunnels as a hibernation roost for bats
and it would therefore be of great interest to study their
re-colonisation once they were re-opened.

     The owner was initially somewhat reluctant to sanction
the re-opening of the tunnels, partly on account of an
inherent antipathy towards bats and aversion to seeing more
of them around his garden. After listening to the case for
the conservation of bats and their roosting sites, however,
he generously agreed that the work could go ahead.
Unfortunately it was not possible to use any form of mech-
anical digger because of the difficulty of access, and
there was therefore no alternative but to call on parties
of volunteers armed with spades, shovels and mattocks.

     The first work party assembled on 2nd October 1971, and
was composed of enthusiastic members of the Norfolk Young
Naturalists. This group removed much of the rank vegetation
and managed to enlarge the area of exposed chalk from about
2m x 1.3m to 5m x 2m. Further enlargements to the chalk
face were accomplished over the next few months by parties
from the University of East Anglia Conservation Corps, the
Coastal Ecology Research Station of the Nature Conservancy
and occasional lunchtime sessions by two of the authors
and other interested persons. The job became extremely

slow because of the necessity to lift the material from the
steadily growing hole and carry it almost nine metres to
the edge of the spoil heap.

The final privilege of breaking through to the tunnel
went to a party of Norfolk Young Naturalists led by J.C.G.
on 4th August 1972. Altogether a total of nearly 250 man-
hours had been spent on the task, and a depth of about five
metres from the top of the chalk to the tunnel had been
exposed. The entrance was subsequently enlarged, mainly by
shovelling soil downwards into the tunnel from the inside,
and later the second tunnel, which was much the larger of
the two, was broken into.

Once the tunnels had been re-opened, detailed plans
were made for erecting grilles over the entrances. Advice
on materials and the spacing of the bars was obtained from
R. E. Stebbings who has had considerable experience of
erecting bat grilles. The grille was constructed and fixed
in position by Hubbard Bros. Limited of Norwich on 1st
September 1972, at a cost of £86. It consists of a 5m
diameter semicircular iron frame, with horizontal bars
17 cm apart and vertical rods 23 cm apart. The frame was
positioned so as to completely cover the entrances to both
caves. It was welded onto supports 23 cm apart hammered
well into the ground and into the chalk. It has a hinged
central gate 60 cm square which is kept padlocked. This
grille allows bats to pass freely into and out of the
tunnels and also permits ready exchange of air which is an
important factor for the hibernating bats. The whole
structure is extremely rigid and remains unscathed after
more than one abortive attempt to damage it or break into
the tunnel.

Mapping of the Tunnels

The lay-out of the tunnels is shown in Fig. 2. This
map is the end-product of several hours of surveying by
P. and J. Buckley. The major problems in surveying arose
from the overall shape of the tunnel system, the darkness,

the irregular floors and different levels, and in some
parts the confined working space. The methods used were
broadly to take bearings and measurements from a series
of fixed points which consisted of candles stuck to the
tops of ranging poles. The usual army prismatic compass
proved to be very difficult to use in the darkness, but a
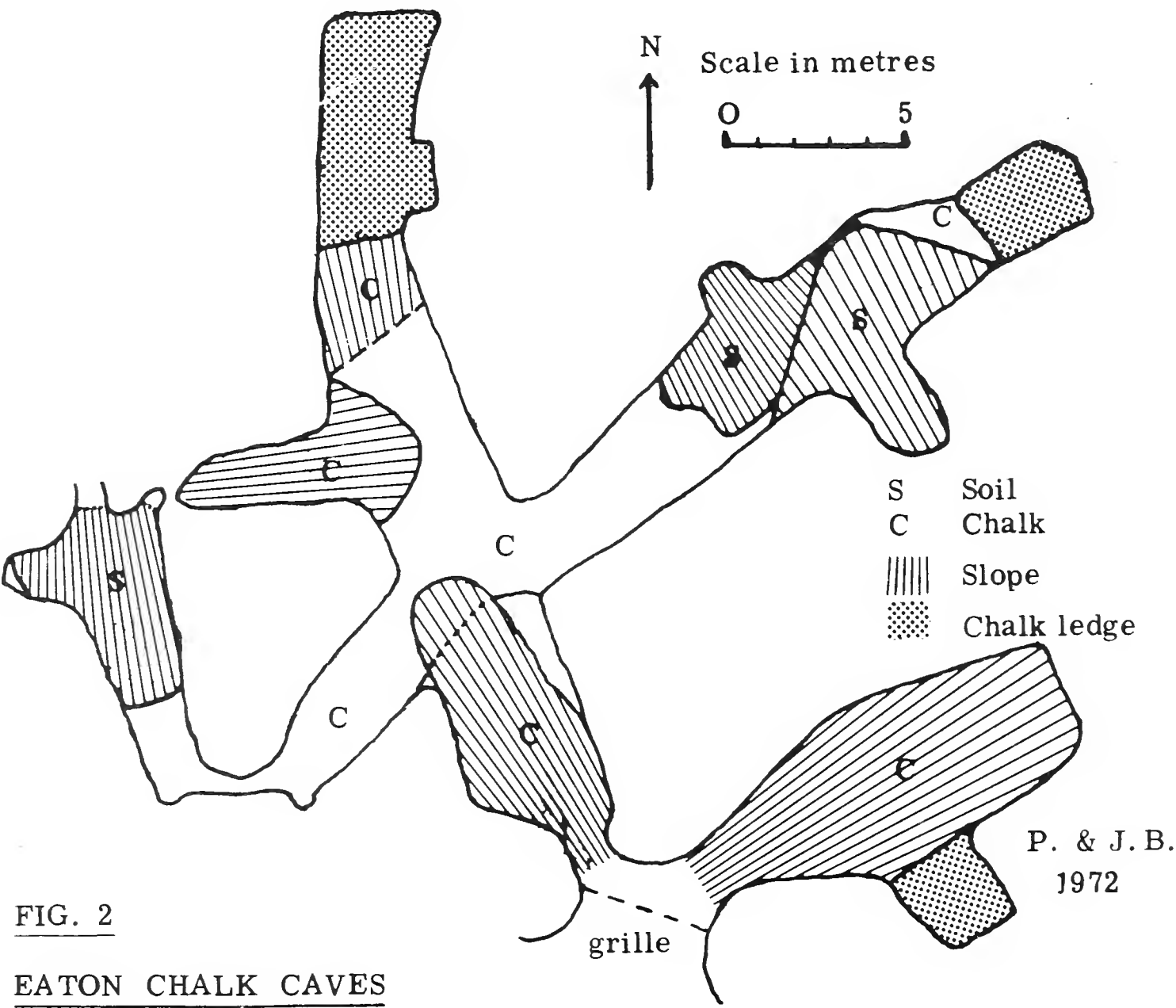Suunto compass was found to be more suitable when
illuminated by torch-light.

N
Scale in metres
O   5

S   Soil
C   Chalk
||||| Slope
░░░ Chalk ledge

P. & J.B.
1972

FIG. 2

EATON CHALK CAVES

Future Access Arrangements

It has been agreed with the owner that access to the tunnels should be controlled by the Nature Conservancy, but they are available for serious scientific investigation. Because of the risk of disturbance to roosting bats and interference with the studies being conducted into the recolonisation of the tunnels by bats, no permits for entry will normally be granted during the winter (1st September to 31st March). During this period only the minimum number of visits will be made to the caves, to record the numbers, species and distribution of bats roosting within them. All the observations on the bats will be made by R. E. Stebbings or persons authorised by him. During the summer months geologists may visit the caves by arrangement with the Nature Conservancy, 60, Bracondale, Norwich, NOR 58B, to whom all enquiries should be made.

Acknowledgements

We would like to express our gratitude to the owner of the chalk pit, Mr. P. H. Pointer, for his helpful co-operation during the re-opening of the tunnels and for his continuing generosity in allowing his property to be used for research purposes. We would also like to thank Mr. J. Woodrow for valuable information about the history of the chalk pit. This information was supplemented by documentary evidence made available by Norwich City Library and Norwich Castle Museum. Finally we would like to say a word of thanks to all the people whose combined efforts resulted in the re-opening of the tunnels.

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Hooper, J.   1965   The Study of Bats in Devon, Journal Devon
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SHINGLE STREET, SUFFOLK: AN ANALYSIS OF A GEOMORPHIC CYCLE

R. E. RANDALL*

Abstract

The resultant of shingle movement in the littoral zone at Shingle Street is to the north in contrast with much of the east coast of England. This anomaly is associated with the growth of North Weir Point, and water movement in the Ore estuary. Growth of Shingle Street shingle spit is traced over a period of 70 years and related to the external controlling factors of material supply, waves, currents and protection. Suggestions are made for student use of this or similar areas to gain further understanding of coastal morphology.

Introduction

In recent years a growing number of schools, field-study centres, colleges of education and universities have included the measurement of physical processes in the field within their environmental science curricula. This activity is to be encouraged since it is one of the most effective ways to lead both students and teachers away from the misconceptions that derive from some of the older textbooks in geology and physical geography. Genèralizations and theory based on insufficient field data have resulted in gross oversimplification of the real-world situation. Dury (1963) has pointed out several problems associated with the river in geographical teaching but the coast too has suffered similarly. This is a great pity, because the coast is not only accessible to many students, it is also a very rapidly changing dynamic system which well repays repeated observation and mensuration even at

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short intervals.

The principal aims of this paper are to describe one such rapidly changing system, the shingle beach at Shingle Street, and to recommend further work that students could carry out at this or other coastal locations.

Shingle Street is a part of Bawdsey Parish, on the coast of Suffolk, England. It is situated on the west bank of the estuary of the River Ore, opposite North Weir Point, the distal end of Orford Ness.

The history of Shingle Street, the River Ore and North Weir Point are closely bound together and must be regarded as a single entity when attempting to understand the physiographic development of the district. The area of prime interest is an accumulation of shingle east of the sea wall in the northern part of the hamlet. It is composed of a series of apposition banks enclosing several lagoons. Projecting northwards and making an acute angle with the mainland is a shingle spit behind which an arm of the sea is situated (Fig. 1).

Although several writers e.g. Carr (1965, 1969, 1970, 1972), Carr and Baker (1968), Kidson and Carr (1959),Kidson, Carr and Smith (1958), Steers (1926) have previously dealt with the total locality, including Shingle Street, much of their work has focussed on Orford Ness; but Cobb (1956, 1956/7) specifically investigated Shingle Street.

It is widely recognized that the general direction of long-shore drift of beach material along the east coast of England is southward, as is immediately visible from the morphology of Orford Ness itself, Holderness and Landguard Point. However it has become increasingly obvious as investigation continues that this is not true for all the coast (Williams 1956). Shingle Street is an example of one of these anomalies, where growth is in a northerly direction up the estuary of the River Ore. Protection afforded by North Weir Point from the dominant north-easterly winds may in part explain this

but wave-direction theories are rarely sufficient to
explain such phenomena totally. Robinson (1955) found
that on the south coast of England residual water move-
ments helped to explain such features.

Pre-1893 History - The Cycle

        Early maps and charts show that in the Middle Ages
Shingle Street had a cliffed coast (Norden 1966) but since
that time there has been continuous change. This has
involved the cyclic increase and wane of North Weir Point
with concomitant effects at Shingle Street. At the
commencement of a cycle North Weir Point lies in a
northerly position and there is a series of irregularly
shaped islets and banks to the south of it. This situation
is followed by a period of consolidation during which the
Ness extends southwards incorporating the islets and banks
until it is level with the southern extremity of the
hamlet. At this stage it becomes unstable and is broken
by a severe storm so that the Ness reverts to its northerly
position and the islets and banks reappear. During this
cycle Shingle Street becomes gradually more protected and
then suddenly is exposed once more.

        An example of this cycle can be traced on successive
maps (in Norden, op. cit.) by Kirby (1736), Hoskisson
(1783) and Carey (1807). For the nineteenth century a
more accurate picture can be gained from the Admiralty
Charts of 1811, 1847, 1892 and 1894 and the Ordnance Survey
maps of 1838 and 1879. This cycle culminated with the
storm of November 18th-20th, 1893, when the last kilometre
of the Ness was driven landward, allowing the sea to beat
on Shingle Street unhampered for the first time in a
century. The Ordnance Survey 25" map of 1904 provides the
first recorded occurrence of the shingle beyond high water
mark at Shingle Street: this probably dates from the 1893
storm. At this time the sea most likely reached as far as
the main ridge, while the Ore flowed out to sea via the
sea-arm and the Lagoons (Fig.1).

Fig. 1   Location and topography of Shingle Street

The Present Cycle

The twentieth-century stages of the cycle at Shingle Street have been recorded in considerable detail by surveys and aerial photographs since 1942. Unfortunately there is little accurate evidence for the period between 1904 and 1942, except an Ordnance Survey revision of the southern portion of the 25" map in 1924. Fig. 1 (inset) shows the series of lagoons numbered 0 - 7 from the south by Cobb (1956) which diversify the beach at Shingle Street. These lagoons fall into three categories. Lagoons 0 - 3 are tidal (by seepage) though separated from the open sea by a shingle bank. They are all floored with alluvium and were almost certainly part of the bed of the Ore. They are visible in embryonic form on the 1904 Ordnance Survey map and were permanent features by 1924. During the post-war period these lagoons began to be infilled and they were greatly reduced in size by landward movement of material between 1948-1953. As a result of the 1953 storm surge these lagoons virtually disappeared and now are seen only as depressions in the shingle. Lagoon 4 is a larger example of the same type and has been slower to fill in. Lagoons 5, 6a and 6b are much further inland than the others, and were probably originally man-made. Lagoon 5 appears on the 1904 Ordnance map and may well be a borrow-pit from which material was taken to construct the sea-wall. (Lagoons in a similar position farther south by Martello Tower 2 have sides and floors of laid septarian blocks.) Lagoons 6a and 6b are situated in an area where shingle was worked during World War II and neither were in evidence on the 1904 Ordnance Survey Map. These lagoons do not have an alluvial floor above the London Clay (Fig. 2).

Lagoon 7, the largest and northernmost of the lagoons is also the most interesting physiographically. This lagoon was not in existence in 1904 when both it, and the sea-arm immediately to the north, were a part of the Ore estuary. Although there is no documentary evidence,

local residents say that North End Spit had begun to form
by 1926, causing an embryonic Lagoon 7. At this time
North Weir Point was considerably north of its present
position: thus growth of the spit and northward movement
of material was not initiated under protection of Orford
Ness, though the latter may have had some effect on wave
incidence, especially since the dominant winds on this
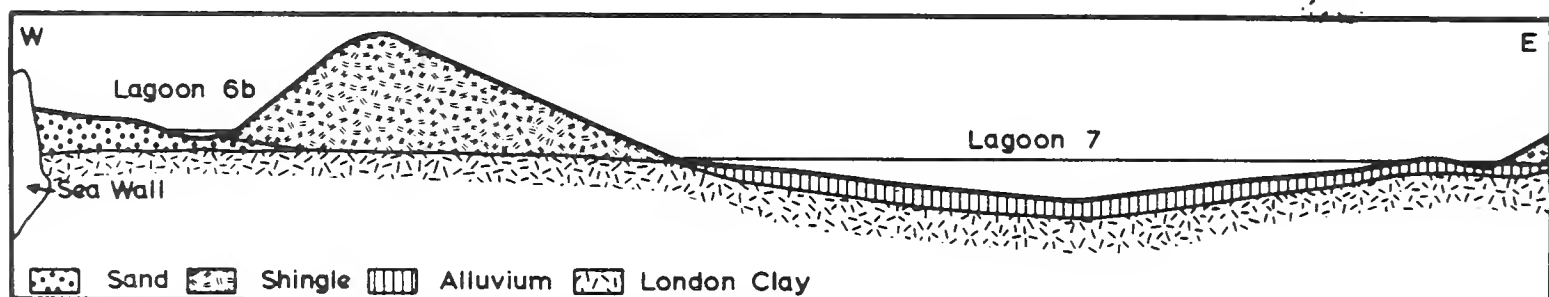coast are from the north-east.

Fig. 2   Geological cross-section of Shingle Street
         through Lagoons 6b and 7

The development of the sea-arm and Lagoon 7 can be
traced from a succession of maps (Appendix 1) and aerial
photographs (Appendix 2) which have been employed in
drafting figures 3 - 6 inclusive. The following principal
components of change can be detected:-

1.   Removal of shingle by man 1939-1945, giving the
      irregular coastline morphology visible on
      Figure 3, and the 1945 air photograph (Fig. 4).

2.   Development of recurved hooks on the sea-arm
      by 1945 (Fig. 4).

3.   Reversion to a regular coastline on the west
      bank of the River Ore (Fig. 5).

4.   Very rapid northward growth and accretion of the
      sea-arm 1945-1951 (Table 1).

5.   Considerable westward movement of shingle
      following the 'Great Tide' of 1953. The develop-
      ment of a storm-ridge on the east side of
      Lagoon 7; 'fulls' smoothed over and 'lows'
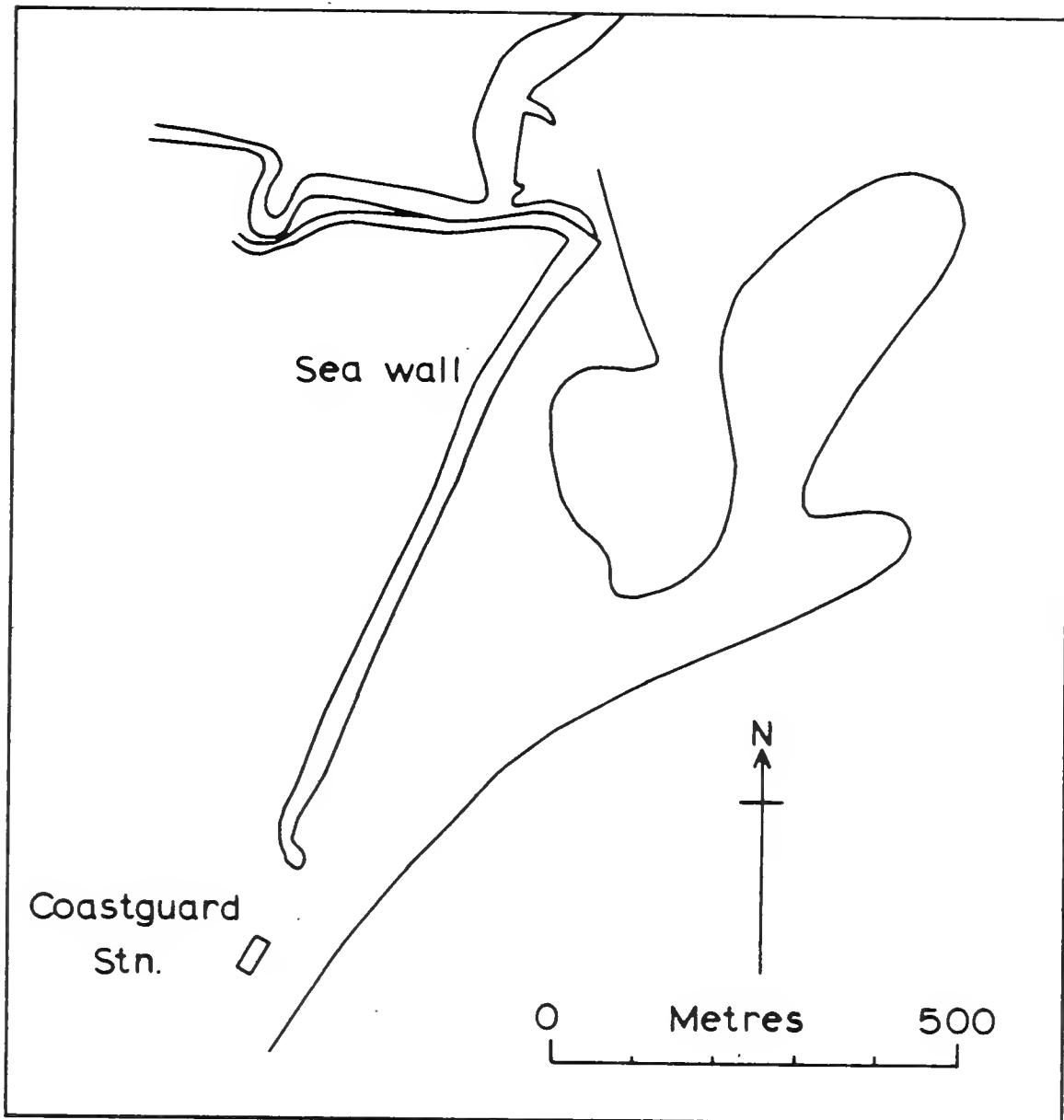
Fig. 3   Manuscript map of Shingle Street, by
         Suffolk Rivers Catchment Board, 1942

filled in (photographs of 4th February, 1953)
Fig. 4. A reduction in growth-rate of the sea-
arm (Table 1), corresponding to that of North
Weir Point (Carr 1965, p.120).

6.   Thickening of sea-fringe to a maximum in 1955
        (Table 2) and the formation of a 'ness' opposite
        Lagoon 7 (Cobb 1956/7, Plate 1). (The ness may
        be an indication of the way Shingle Street
        receives some of its material (Carr 1965, p.125)

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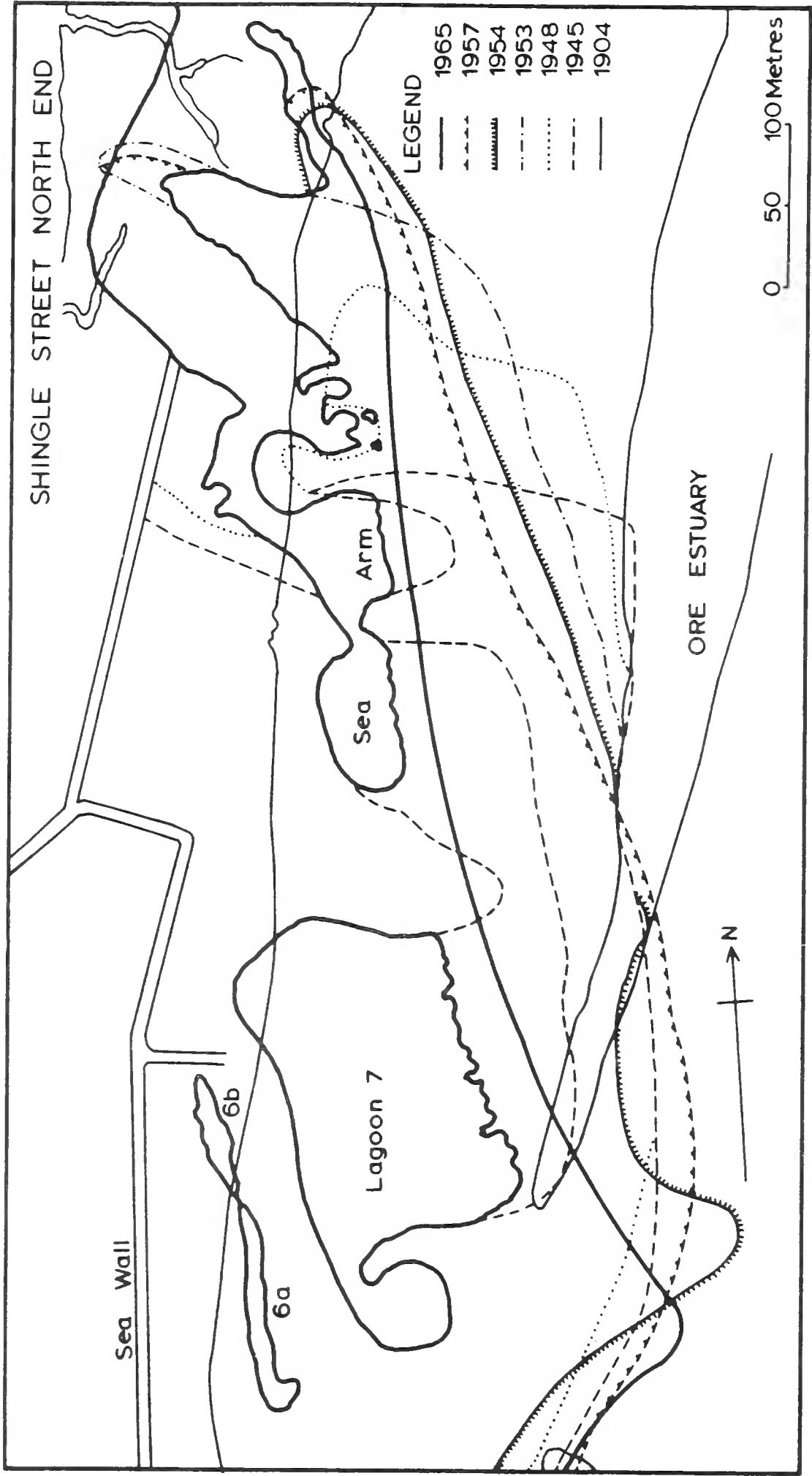
Fig. 4   Composite map showing the changing coast-lines
         at Shingle Street during the twentieth century
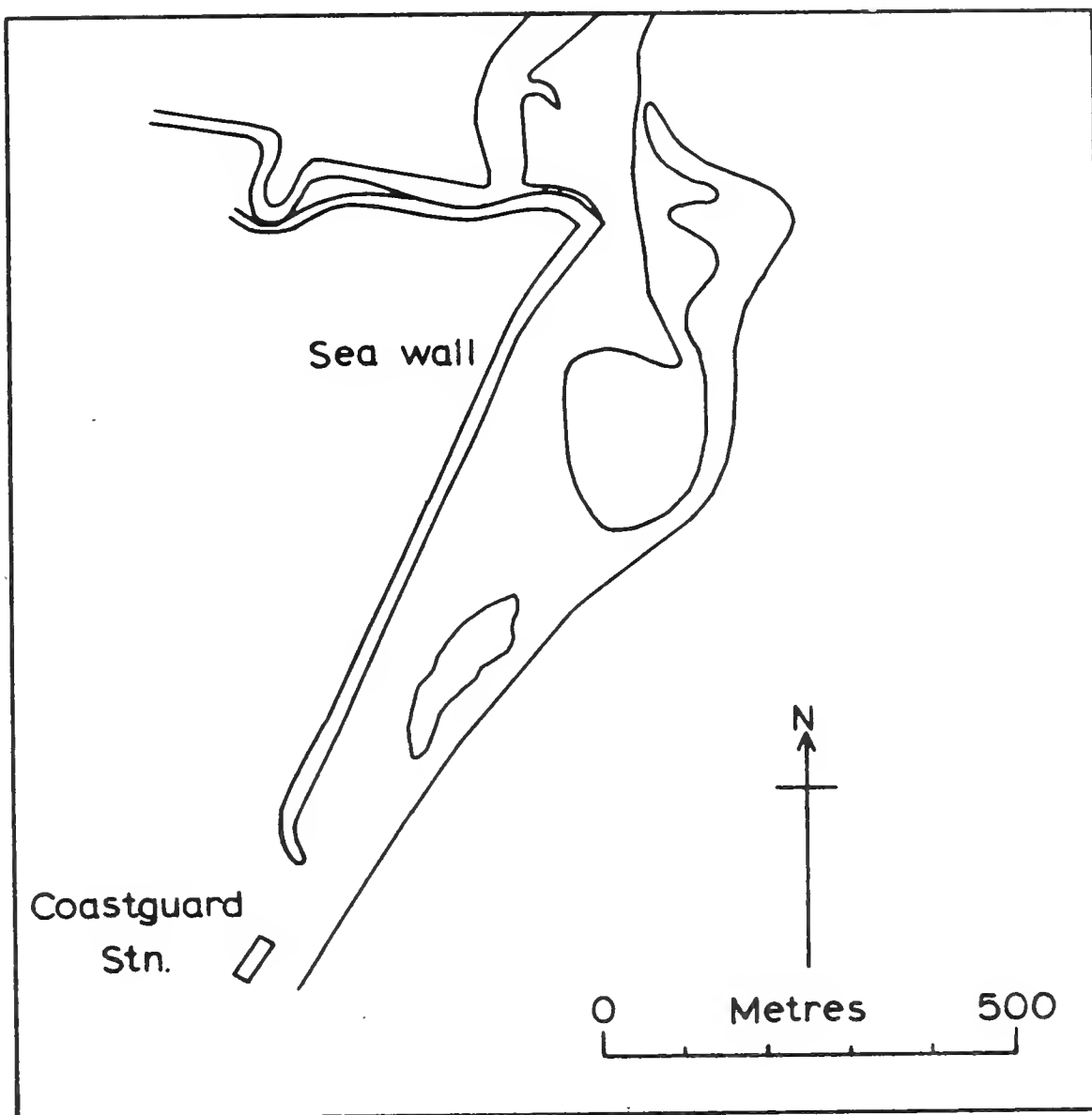
Fig. 5   Manuscript map of Shingle Street, by Norfolk
         and Suffolk Rivers Catchment Board, 1946

but the full complexities of the shingle move-
ment are still unresolved (Carr 1972).

7.   Erosion of the eastern side of the sea-ridge
     from 1956 (Fig. 4). It was from this date
     that the northern part of Shingle Street became
     protected by Orford Ness. The growth of the
     latter caused a constriction of the Ore channel
     and hence erosion of the west bank, see Myrick
     and Leopold (1963).

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TABLE 1

NORTHWARD ELONGATION OF SEA-RIDGE, 1945-1970

Date	1945	1948	1951	1954	1956	1961	1965	1968	1970
Increase (metres)	–	129	50	51	14	26	20	4	2
Length (metres)	0	129	179	230	244	270	290	294	296
Source	Air photo	Air photo	Air photo	Air photo	Cobb (1956)	Air photo	Author	Air photo	Author

TABLE 2

WIDTH CHANGES OF SEA-RIDGE AT SOUTHWESTERN CORNER OF LAGOON 7, 1945-1970

Date	1945	1948	1952	1955	1961	1965	1968	1970
Width (metres)	60	85	86	91	46	33	38	31
Source	Air photo	Air photo	Air photo	Cobb (1956)	Air photo	Author	Air photo	Author

8.   Continued erosion of the sea-ridge and slow
     northward elongation of the sea-arm to 1961
     (Fig. 6). A bodily westward movement of the
     whole ridge caused a narrowing of the Lagoon
     7 outlet, which was finally sealed in 1962.
     Shingle Street North End is now fully protected
     by North Weir Point.

9.   Survey of 1965 (Fig. 1) by author. Highest
     point of sea-ridge at Shingle Street coincident
     with 1904 location of distal point of Orford
     Ness. Reduction in size of Lagoon 7 caused by
     shingle infill; a further spread of shingle
     over the original Lagoon 7 outlet; a decrease
     in area of recurved spits as sea-ridge moves
     further west.
     The latest survey of the area was made by the
     author in October 1970. This survey and aerial
     photographs of March 1968 show that most of the
     trends experienced earlier were continuing.
     North Weir Point was growing further southwest-
     wards and the sea-ridge at Shingle Street was
     consequently encroaching upon Lagoon 7 as the
     swash and ebb channels of the River Ore were
     displaced. At its greatest extent the north
     shore of the latter was 175m in length; in 1970
     it was barely 78m. The sea-arm had silted up
     further and more shingle had been thrown between
     it and Lagoon 7. These were joined in 1961 but
     by 1970 were 90m apart. Little material appeared
     to be reaching North End Spit: it was 296m long,
     fractionally more than in 1965, but the northern
     portion was underwater at spring tides and the
     distal point had been turned westwards.

Shingle Movement

     The source of the material at Shingle Street and the
sequence of its movement are intriguing facets of the

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Fig. 6   Vertical air photograph of Shingle Street in
         October, 1961. (V-AK 93/95. Courtesy of
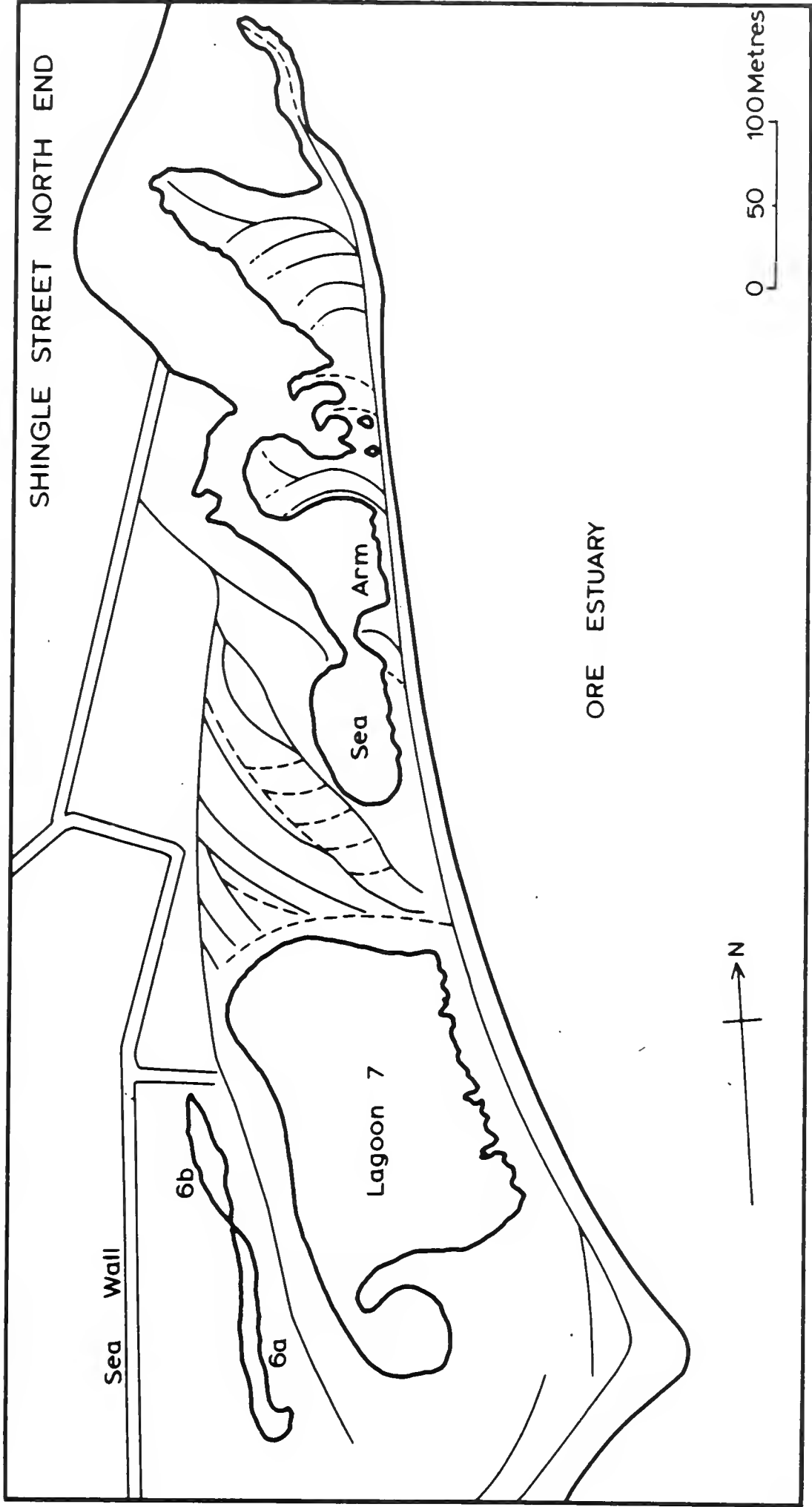   J. K. St Joseph, Cambridge University)

Fig. 7   The direction of Shingle ridges at Shingle Street

study. Figure 7 shows the position of the fulls and lows
in the area of Shingle Street under observation. There
are two series of ridges, an older group to the west of
Lagoon 7, bent southwards, and a newer one to the east,
bent northwards. The greater part of the shingle is flint,
which initially came from the Chalk, though it has reached
Shingle Street via wave action on the glacial deposits of
the coast. It has also been suggested that offshore banks
and shoals might produce some beach material(Kidson 1963).
The most likely immediate source of material is the
southward moving shingle of North Weir Point. Work in the
Ore estuary by Kidson and others(Kidson and Carr 1959,
Kidson et al. 1958),using shingle marked with radioactive
tracers, shows that, at the present day, movement of
shingle in the off-shore zone is virtually non-existent so
that material from banks and shoals could be discounted as
a source of supply. Experiments showed that if material
drifted south to the North Shingle Bank (immediately south
of North Weir Point) it was unable to cross the estuary to
the Shingle Street side but merely progressed slowly towards
the river channel and contributed to the southward pro-
gression of North Weir Point. However, other material
which drifted to the South Shingle Bank further south and
further seaward, crossed the estuary via the shallow river
bar, and reached Shingle Street south-west of Lagoon 7.
This line of movement can always be seen at low tide by a
line of broken water and occasionally shingle appears as
arcuate islets.

For a spit to elongate successfully two conditions
must be fulfilled. There must be a plentiful supply of
material at the same time as conditions are favourable for
its movement, and, since this coincidence is unpredictable,
conditions may exist for a considerable period without
movement occurring. This could be why events at Shingle
Street appear to be sequential and cyclic, yet irregular
over short periods.

Shoals and banks on the sea floor prevent the free
approach of waves. There are two cordons of banks off the
Suffolk shore, the inner of which, the Aldeburgh Napes and
the Shipwash, are only covered by about 2 metres of water
at low tide and protrude as islets in places. Much closer
inshore, landward of the 6 metre line, there is extensive
development of shingle flats, nearly exposed at low tide.
Even the main channel of the Ore estuary is only 2 metres
deep. These flats are a marked barrier to large waves at
low water thus limiting the size of waves able to attack
Shingle Street and affecting the obliquity of their approach
to the coastline.

Waves are important agents in moving beach material
and they are controlled by the winds of the area, which
come most frequently from south and west. It is from this
direction also that most storms originate. Southwesterly
winds are prevalent but not dominant. The greatest fetch
is from the north-east quadrant, from the East Frisian
Islands, off the North coast of Holland, a distance of only
420km. The fetch from all points to the north of this is
ineffective because of the shielding influence of Orford
Ness. Thus, even the dominant waves are not as great as
might be expected. (It is interesting to note that south
of Shingle Street where southerly drifting is resumed, the
north-easterly dominance is much greater, there being a
line of fetch to Norway.) Furthermore, the mass of shingle
to the south of Hollesley Bay acts as a proctection against
the south-easterly winds of 160km fetch. It seems there-
fore that the main northward movement of material in the
Ore estuary is not at present due to normal longshore
drifting, and waves only aid in the supply of suspended
material.

Local currents are basically tidal. At Shingle Street
the flood tide flows northwards to Slaughden, while water
pours from the estuary and its tributaries in a southerly
direction on the ebb. In fact water is still leaving

Orford Haven when the flood begins within the bay. The
juxtaposition of various currents in this anomalous area
produces conflicting wave systems.

Although even strong currents are unable to shift
shingle alone, they play an important auxiliary part in
moving shingle lifted into suspension by breaking waves
(Steers 1953, p.16). Similarly backwash-motivated
material may be affected. In the Ore estuary the current
flow is strong, Carr (1965, p.120) suggests seven knots,
and steady enough to have an important effect, especially
since the northerly current occurs with a rising tide,
lifting the same shingle several times and shifting it
considerably.

It can be seen that the area of overall northward
movement is limited to a small region within or near the
estuary. The actual building of fulls is done by waves,
generated by strong southerly winds but these occur too
infrequently to be the main transporting agent; currents
transport shingle lifted into suspension by waves.

Conclusions

It would appear that the physiographic development
of Shingle Street during this century is as follows. South-
ward moving material on Orford Beach reaches North Weir
Point and separates into two portions. That reaching the
South Shingle Bank crosses the Ore by the estuary bar and
accumulates between "The Beacons" and Lagoon 7. Some of
this material continues to move south under the aegis of
normal longshore drifting while the rest moves north under
combined wave and current action within the estuary.
Variations within the cycle can be explained in terms of
supply of shingle. During the period from 1893 to 1920
little material crossed the bar and thus little action
occurred. Between 1920 and 1953 a good supply of shingle
enabled considerable accretion north of "The Beacons" and
starvation of the beach to the south occurred. (Since the
Ordnance Survey revision of 1924, HWMOT has moved over 150m

inland near the coastguard station.) Since 1953 a smaller
amount of material has crossed the bar, and Shingle Street
has become more protected. Thus, less material is avail-
able to move north; hence the narrowing of North End Spit.
But at the same time a decrease in encroachment south of
"The Beacons" has occurred since longshore drift continues
with the material which is available. If earlier records
are any guide, North Weir Point has a considerable distance
to grow southwards before becoming unstable once more.

Further Research

It will be interesting to note what changes occur at
Shingle Street when it is no longer at the mouth of the
estuary but well inside it. School and college students
could easily assist in this research. The following small
projects might be carried out by visiting parties:

(i)   measure the width of the sea-ridge at the
       south-western corner of Lagoon 7. This
       would add to the data in Table 2 and thus
       give some idea of the lateral shift of
       the Ore estuary.

(ii)   measure the length and orientation of the
       north end of the sea-ridge. This would
       be a reliable way of assessing the amount
       of material moving northwards.

(iii) students visiting the area for a period
       of more than one tide could paint pebbles
       (with orange marine paint?), place them
       on the foreshore, and observe distance and
       direction of movement.

Although only one location has been described in this
article, the investigation of archival evidence, followed
by practical work on site, could be carried out for very
many coastal features of the British Isles. Obviously
lowland areas of accretion such as dunes or sand and
shingle spits are much easier to work with then slowly
changing sea cliffs and other erosional features. In some
places however, erosion causes much local concern and
could profitably be measured. The major significance of
this study is the day-to-day dynamism that is revealed
in coastal geomorphology, a process and time scale often
overlooked in teaching in the field.

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APPENDIX 1

CARTOGRAPHIC SOURCES

Date Published or Surveyed	Reference Number	Source
1811	101 (A1)	Hydrographic Office
1838	48 N.E.(1", 1st edition)	Ordnance Survey
1847	2052 (A1)	Hydrographic Office
1872-8	2052 (B2)	Hydrographic Office
1879	90 (6" edition)	Ordnance Survey
1892	2052 (B10)	Hydrographic Office
1894	2052 (B12)	Hydrographic Office
1904	77.16 (25", 2nd edition, revised 1902)	Ordnance Survey
1924	Revision of parts of sheet 77	Ordnance Survey
1942	Manuscript map	East Suffolk Rivers Catchment Board
1946	Manuscript map	Norfolk and Suffolk Rivers Board

APPENDIX 2

PHOTOGRAPHIC SOURCES

Date Taken	Reference Number	Source
16.10.1945	4435 RS 106G/U.K./ 929	R.A.F.
11.7.1947	S 56-64	J.K.St.Joseph, Cambridge Univ.
24.6.1949	CQ 066-069	" " "
2.8.1951	HC 046-048	" " "
21.3.1952	Various	R.A.F.
4.2.1953	V 0049-0051	Ministry of Housing and Local Government
23.6.1954	OF 53-54	J.K.St.Joseph, Cambridge Univ.
3.3.1955	0180 F 22 58/R.A.F./ 1672	R.A.F.
6.6.1956	SW 15-18	J.K.St.Joseph, Cambridge Univ.
16.6.1958	WM 49-53	" " "
17.6.1959	YJ 50-54	" " "
15.6.1961	V-X 86	" " "
28.10.1961	V-AK 93-95	" " "
1.6.1963	AHB 86	" " "
10.6.1965	AKZ 55-61	" " "
26.4.1968	AUG 50-52	" " "

ENVIRONMENTAL GEOLOGY OF SHERINGHAM

(Report of a Field Meeting held 16 September 1972)

B. M. FUNNELL*

Environmental geology is concerned with the effects of geology and geological processes on human activities. The Sheringham district provides several examples of such effects, which were visited by the Society in the summer of 1972 and are recorded here, although it is emphasised that this is not a systematic account of the environmental geology of Sheringham. The principal locations are shown in Fig. 1.

Mineral Workings

The Drayton Stone Pits Ltd. operates a gravel working (TG 168415) in the Briton's Lane Gravels - a deposit of coarse gravels and sands, probably laid down at the northern margin of the Lowestoft glacial advance of the Anglian glaciation. Most of the gravel is composed of flint with scattered erratics of ganister, dolerite and decomposed acid igneous and metamorphic rocks. The bedding indicates deposition by water flowing in a generally north-ward direction. Now the deposit is terminated northwards by steep slopes fretted by periglacial valleys (Fig. 2). Occasional lenses of glacial till are intercalated in the upper part of the gravels towards the south of the pit. In an east - west direction the Briton's Lane Gravels (Sand and Gravel) are quite continuous as far as Pretty Corner and beyond (Fig. 3).

In places lenses of marl or reconstituted Chalk form part of the irregular basement of glacial till of the mainly Cromer Advance (Loam and Clay) on which the Briton's Lane Gravels rest. Previously lime workings and a lime kiln

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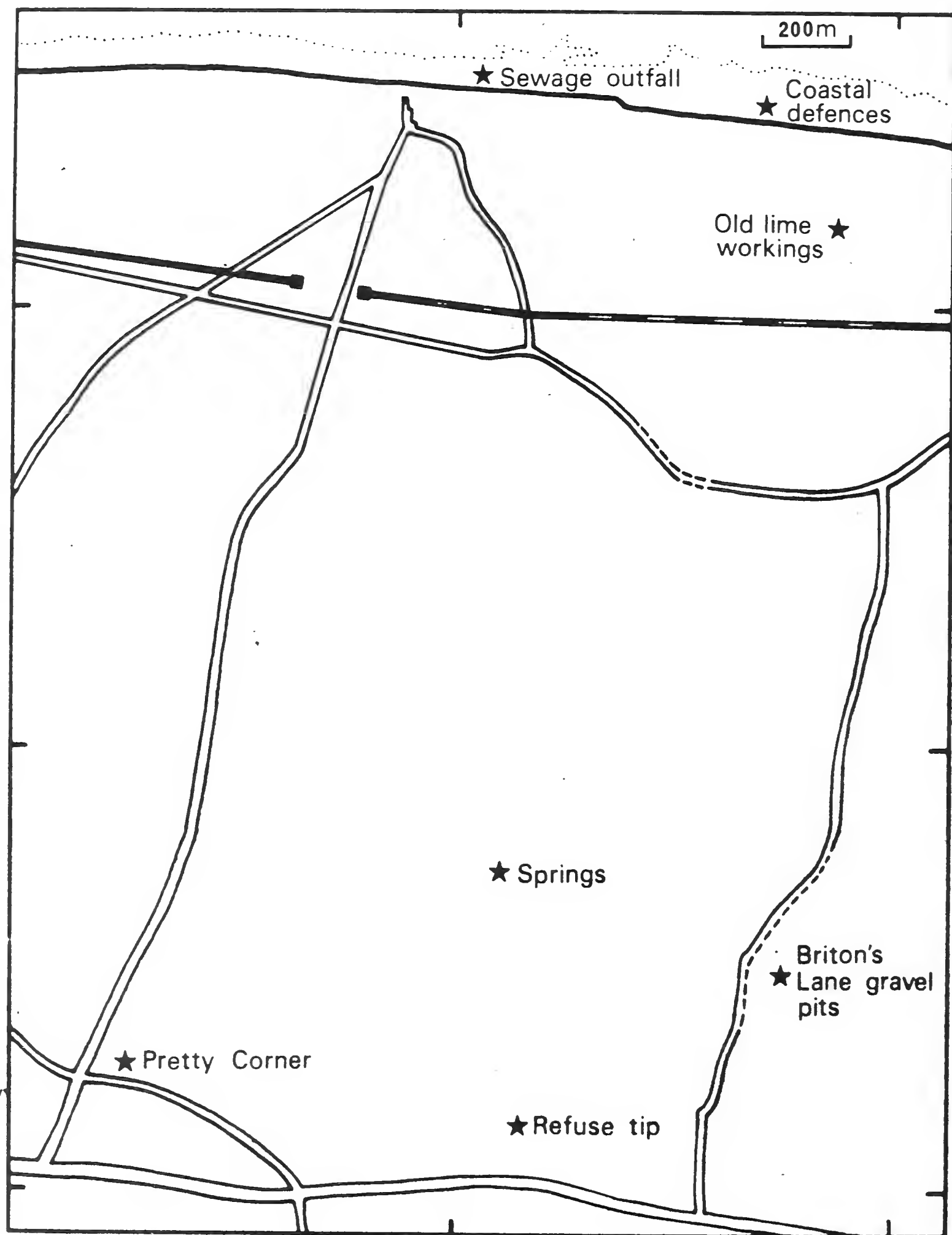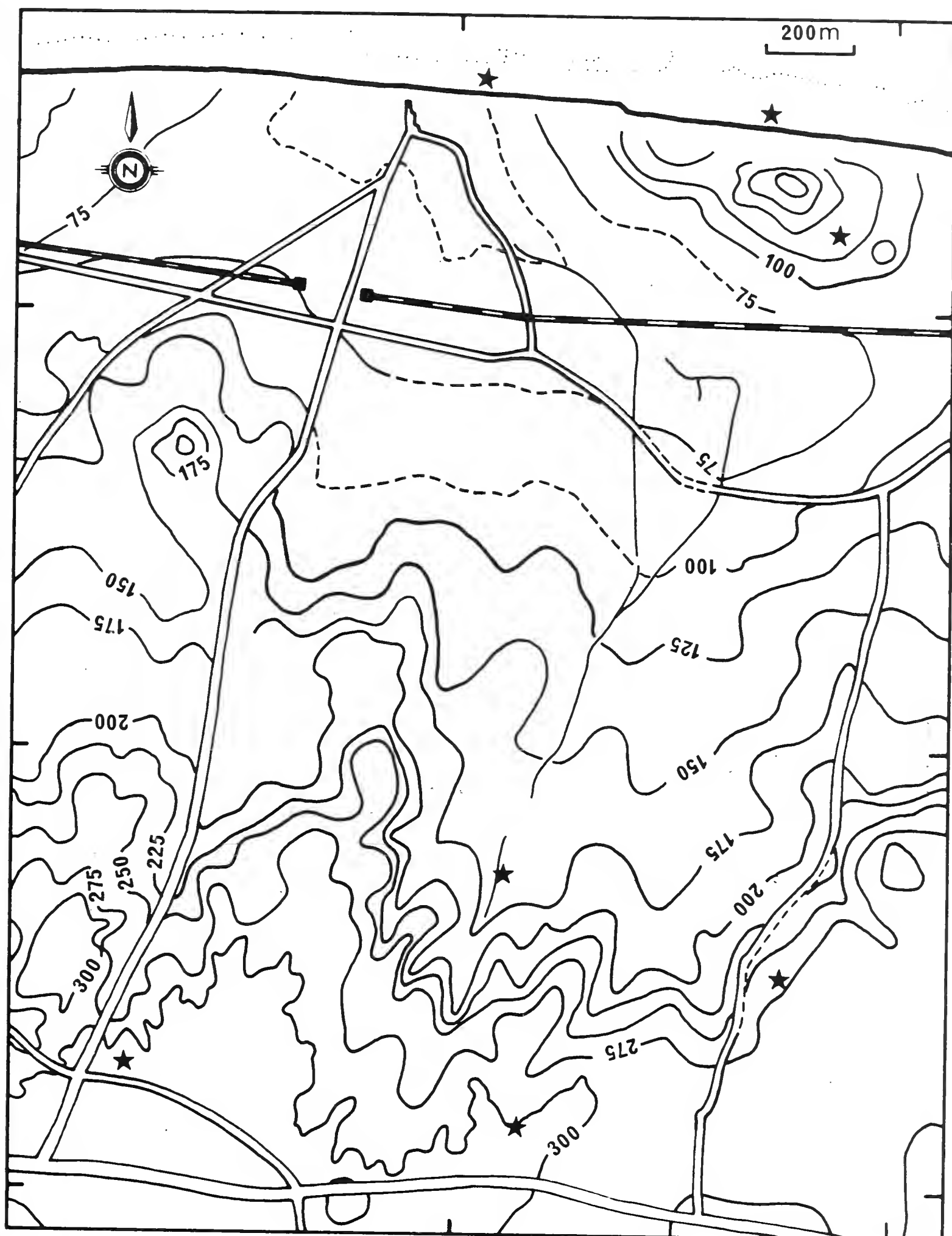
B. M. Funnell
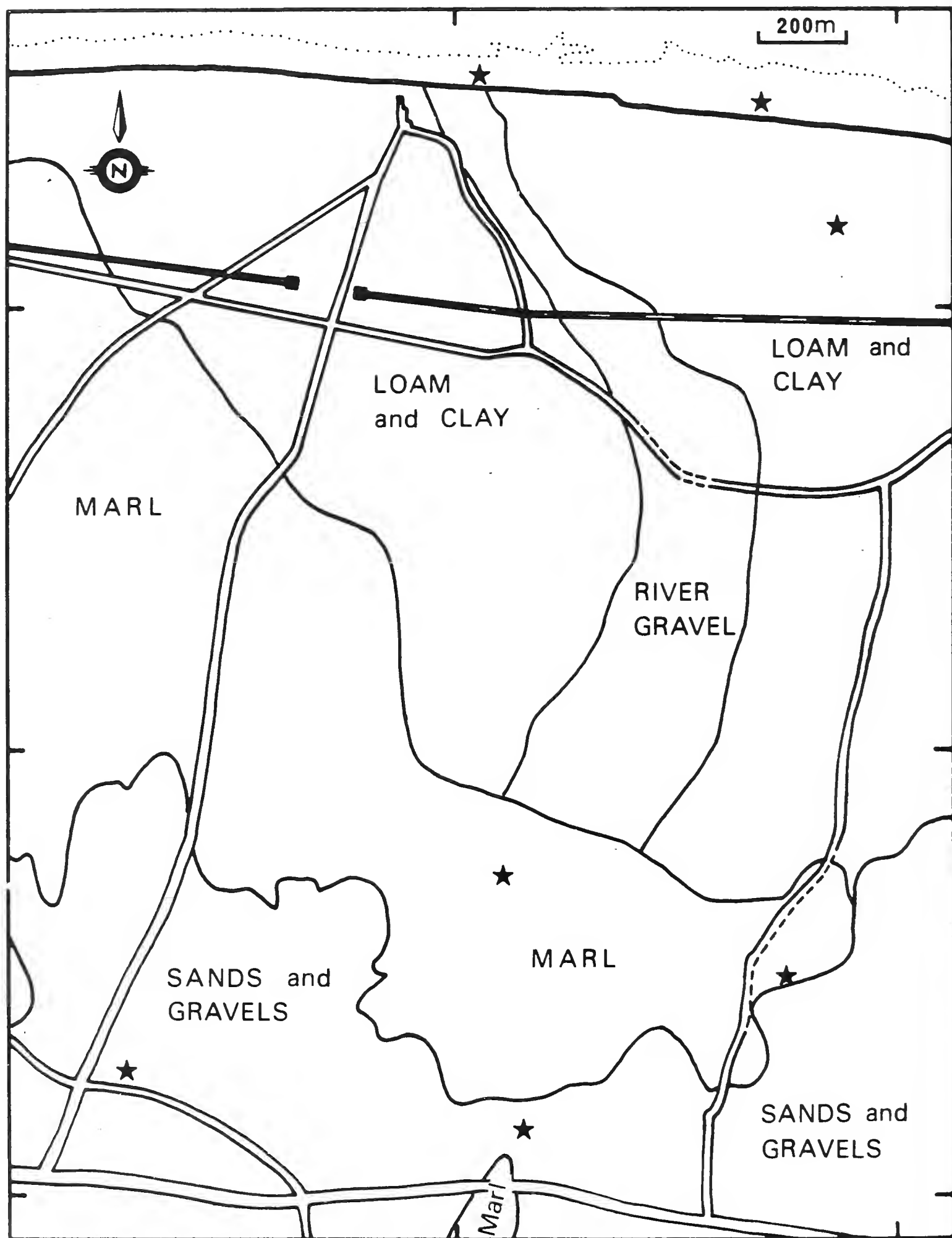

Fig. 1   Key to locations

Fig. 2 Topography

Fig. 3 Geological deposits

were operated in such a lens on the lower ground just east
(TG 169432) of Beeston Hill.

Water Supply

Water percolating into the porous Briton's Lane Gravels
from rainfall accumulates as groundwater held up by the
underlying glacial till complex, (Loam and Clay, with Marl
lenses). Where the periglacial valleys on the north side
of the ridge cut down to the contact between the gravels
and the glacial tills, springs fed by this groundwater occur.
Clearly in the past, higher rates of flow give rise to a
significant river, and associated train of gravel (River
Gravel), which reaches the sea close to the present centre
of Sheringham. Historically these springs (TG 160418)
provided the original public water supply for Sheringham,
although bore-holes sunk by the Sheringham Waterworks
Company in 1818 and 1924 penetrate the glacial till and
draw water from the underlying Chalk formation. Further
development of the groundwater from the gravels is
currently being considered.

Waste Disposal

Domestic refuse was deposited during the 1950's at
the head of one of the periglacial valleys (TG 162412). In
such circumstances the mainly bacterial effluent from
domestic refuse is effectively and rapidly filtered by the
underlying porous sands and represents no threat to the
groundwater supplies in the gravel deposits generally.
Furthermore the restoration of the site by levelling con-
cordantly with the flat top of the ridge is straightforward
and inconspicuous.

Sewage disposal is less a problem of geology than of
coastal currents, although the reliability and economy with
which a sewer pipe can be built a sufficient distance out
to sea will be influenced by the geology of the seafloor.
Near Sheringham the top of the Chalk formation is almost
precisely at sea-level beneath the glacial deposits, and
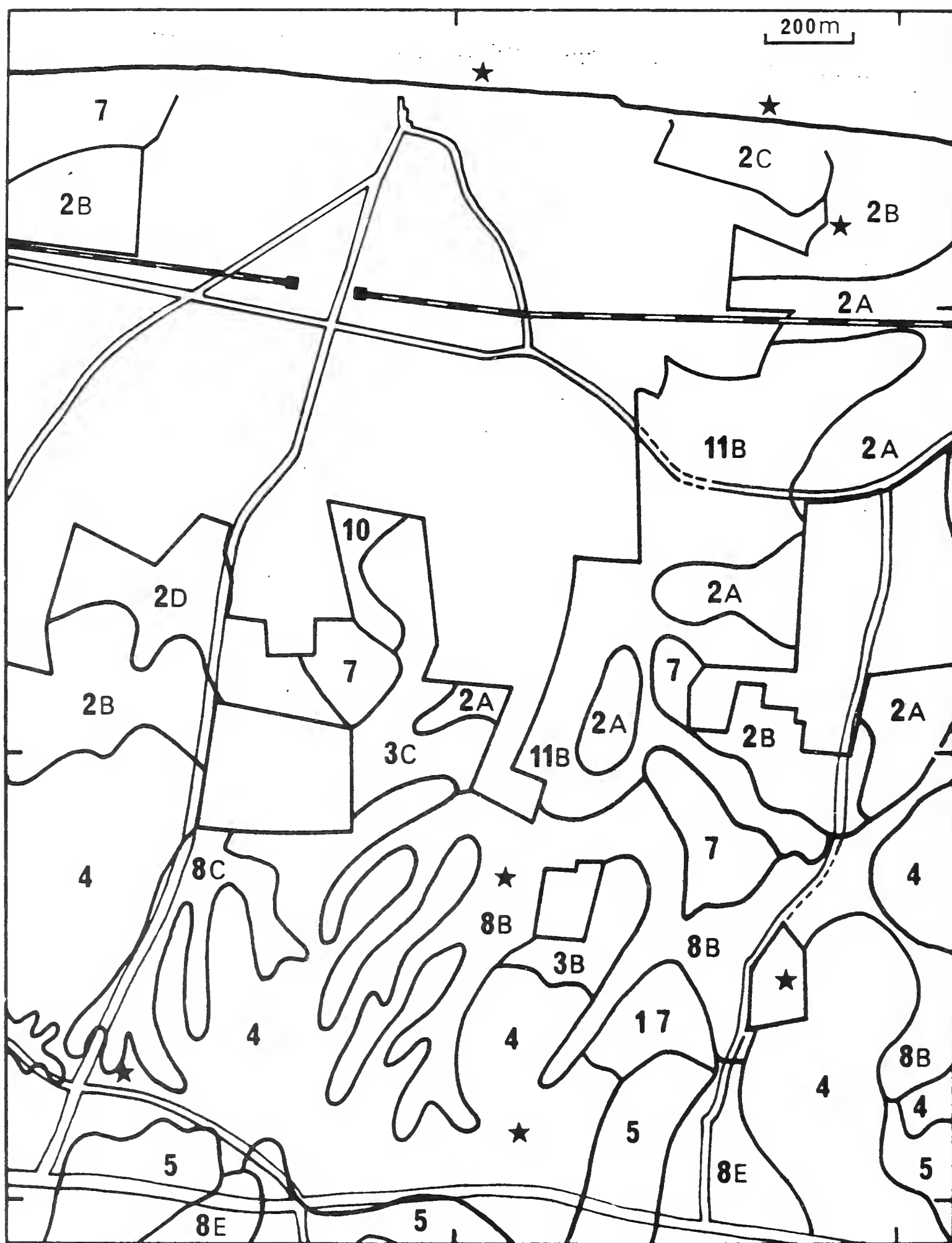
Fig. 4 Soils (for explanation see text)

forms a platform covered by sand and shingle extending offshore. The present outfall extends some distance off-shore from the beach near the centre of Sheringham (TG 161435).

Soils

The geology of the Sheringham district has a strong influence on the local soils (Fig. 4).

On the upper part of the so-called Cromer Ridge, here consisting of the flat or very gently sloping top of the Briton's Lane Gravels, Freckenham Series brown earths and Red Lodge Series podzols are developed (4). In the peri-glacial valleys fretting the steep north-facing slope of the ridge Sheringham Series brown earths are developed on the 70 to 200 cm thick loamy colluvium, which overlies the gravel of the valley floors (8B and 8C). On the very gently sloping ground, which descends southwards from the flat crest of the ridge, Hall Series brown earths are developed on the probably aeolian loams which overlie the gravels in that direction (5).

The lower ground nearer the coast, where it is composed of the wetter loams and clays of the 'North Sea Drift' of the Cromer Advance, produces Weybourne Series gleyed brown earths (2A and 2B). Where the deposits are more sandy or gravelly as on Beeston Hill or adjacent to the northern face of the ridge, however, they give rise to Freckenham Series brown earths (2C, 2D, 3B, 3C and 7). On the other hand, elsewhere, particularly adjacent to the course of the former river, Gresham Series or Sustead Series groundwater gley soils develop on the aeolian loam or loamy colluvium overlying the 'North Sea Drift' (10 and 11B).

Coast Protection

The soft sediments of which the Sheringham cliffs are composed are very prone to slumping and erosion. Even where there is a protective seawall and promenade, the build-up of water pressure in the mixed layers and lenses

of glacial sand and clay, mainly of the Cromer glacial
Advance, can lead to slumping even of previously grassed
slopes. Eastward particularly, beyond the protection of
the seawall, rapid erosion has occurred at the foot of the
cliff, followed by slumping of the clayey deposits in the
lower part of the cliff, and slipping of the sands and
gravels forming for instance the top of Beeston Hill. In
order to prevent erosion of the foot of the cliff the sea-
wall has now been built eastward to a distance of over 1 km
(80 m in the 1930's, 390 m in 1960, and 220 m in 1968) from
the centre of Sheringham to approximately TG 169434. The
face of the cliff behind the seawall is however still
unstable and liable to collapse, and will remain so for
some time to come.

Road Construction

The Holway Road down into Sheringham used to descend
from Pretty Corner (TG 152413), itself on top of the flat-
topped ridge at about 90 m (300 ft.) O.D. following the
route of one of the larger periglacial valleys. The new
road was constructed around 1970, using modern earth moving
equipment that has made it possible to cut across the spurs
separating the different heads of the main valley, giving a
straighter route. Pretty Corner is still an excellent point
from which to investigate the steep-sided heads of these
periglacial valleys, probably formed in times of permanently
frozen subsoil with high summer surface run-off. Because
the ravine-like sides are composed of porous coarse gravel
and sand, they have retained their steepness to the present
day.

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        Sheet TG 13/14 (Barningham-Sheringham). A.R.C.
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The Geological Society of Norfolk exists to promote the study and knowledge of geology, particularly in East Anglia, and holds monthly meetings throughout the year.

Visitors are welcome to attend the meetings and may apply for election to the Society. For further details write to the Secretary: Dr. C. J. Aslin, The University Library, University of East Anglia, NORWICH NOR 88C.
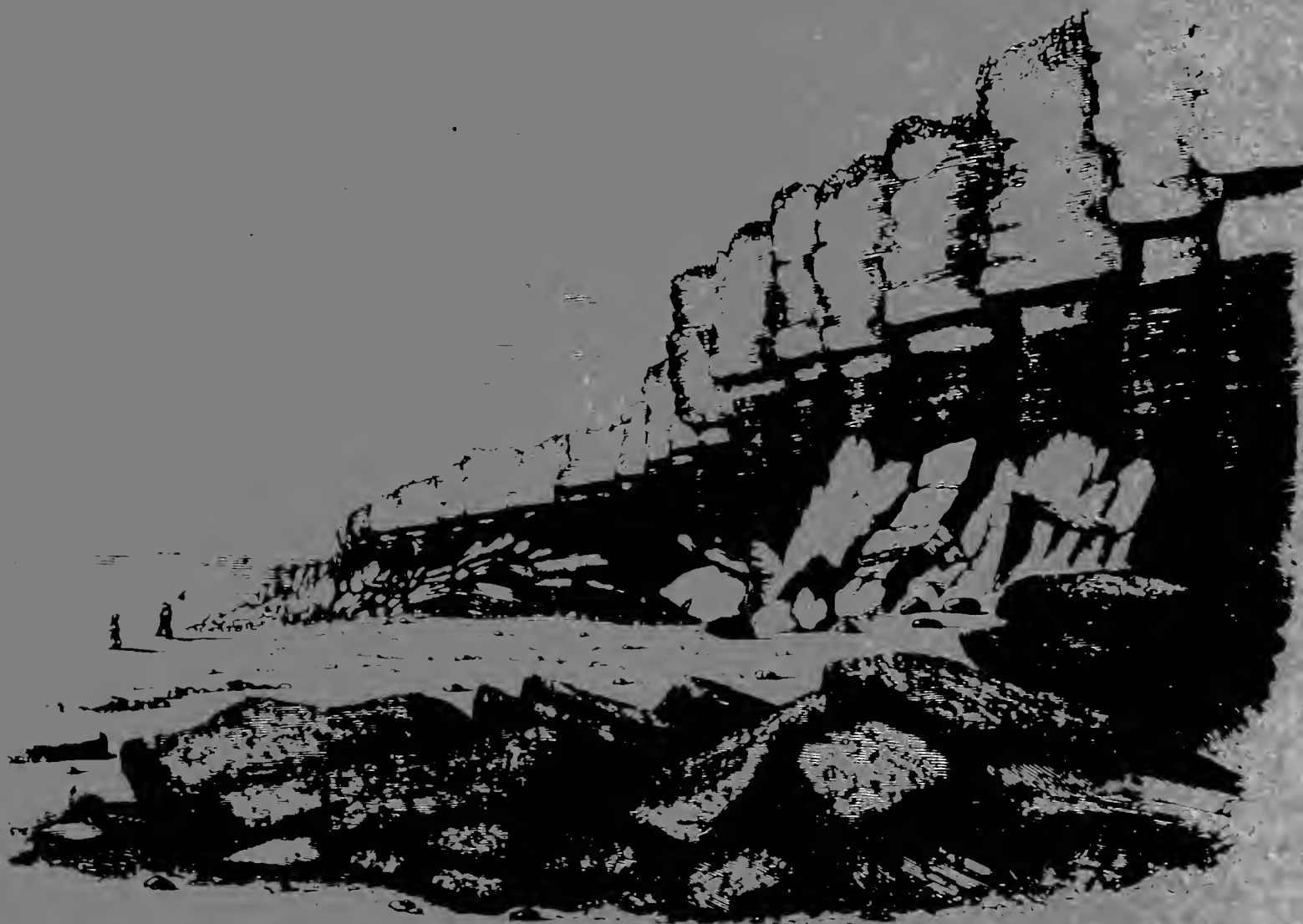
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Copies of this Bulletin may be obtained, 60p (post free), from the Secretary at the address given above; it is issued free to members.

Also available, at 75p (post free), is "The Geology of Norfolk", a 108 page book describing the geology of the county, reprinted by the Society in 1970; members of the Society may buy one copy only at 40p.

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BULLETIN OF THE GEOLOGICAL SOCIETY OF NORFOLK

No 25

CONTENTS INCLUDE:

EDITORIAL

Our President, Brian McWilliams, gave us a stimulating and entertaining Presidential Address in the autumn, and gave me additional pleasure by having the manuscript of the address with him, so that it can be printed in this edition despite the earlier editorial deadline. In taking his survey to the middle of the 19th century, Brian leaves room for further contributions to this topic which I hope will be pursued before long.

Roland Randall contributes a further article in this edition, bringing his experience as an extra-mural tutor to our pages and providing further insights into the uses of geology in education.

Our other major item is a further contribution from the Soil Survey of England and Wales, this time on the geology of the Ely District, and as a bonus a new 'Map of the Geology of the Ely District'. Many thanks to the Survey and Richard Seale for permission to publish.

As a result of a decision taken at the Annual General Meeting it has been decided to print an additional single-topic Bulletin annually. These will update and eventually supersede the very popular 'Geology of Norfolk', which will soon be out of print for the second time. Brian Funnell's Bibliography of East Anglian Geology will also be appearing in the near future and will be invaluable in assisting researchers into local geology. His assistance in the production of the 'Bulletin' is likewise invaluable.

Bulletin No. 26 will be issued in September 1974. Contributions should be sent to me as soon as possible and no later than June 30, 1974.

Will contributors please note that manuscripts are acceptable in legible handwriting, although typewritten

copy is preferred. In either case it would be a great help if details of capitalisation, underlining, punctuation, etc., in the headings and references (particularly) could conform strictly to those used in the Bulletin. Otherwise publication may be delayed.

, Illustrations intended for reproduction without re-drawing should be executed in thin, dense, black ink line. Thick lines, close stipple, or patches of black are not acceptable, as these tend to spread in the printing process employed. Original illustrations should, before repro-duction, fit into an area of 225 mm by 175 mm; full use should be made of the second (horizontal) dimension, which corresponds to the width of print on the page, but the first (vertical) dimension is an upper limit only. All measurements in metric units, please.

R.S.J.

We apologise for the late production of the Spring Bulletin, through circumstances outside our control. It it expected that the Autumn bulletin will appear at its usual time during September.

B.M.F.

THE PLACE OF EARLY COLLECTORS IN THE DEVELOPMENT OF
GEOLOGICAL STUDIES IN NORFOLK
(a summary of the Presidential Address for 1973 delivered
October 25, 1973)
B. McWILLIAMS*

The First Collectors

The first collectors of geological material, in
particular fossils, lived in Palaeolithic times and the
association of collections of fossils with the remains of
early man has been described from many parts of the world
(Oakley 1965). Fossils were collected for a variety of
reasons; personal decoration, ritual, religious, medical
or even constructional purposes, as in the use of mammoth
bones in dwellings by Upper Palaeolithic tribes of the Don
Valley. In addition there is evidence for a regular trade
in fossil (and recent) shells among the Upper Palaeolithic
hunters of Europe.

Collections formed for the purpose of study are unlikely
to have valid claims to such antiquity, though Aristotle
(384 - 322 BC) may well have collected geological specimens
as part of his natural history studies, as may have Pliny
(23 - 79 AD) who published on mineral substances and
gemstones in his later books. Subsequent authors relied on
these two writers (Whitehead 1970) rather than on actual
collection and observation, and the classical works were
the standard texts in the scientific expansion following
the invention of printing. Perhaps the real beginnings of
collecting for study are seen when men like Leonardo da
Vinci (1452 - 1519) used the methods of observation and
experiment and so required specimens. At this time most
collectors were merchants who sought to enhance their status,
but they acquired natural objects as well as art works and
classical relics. Geological material became included more

* Castle Museum, NORWICH, NOR 65B.

in collections, particularly 'figures stones' as fossils
were termed, until by the eighteenth century few educated
men did not believe in the organic origin of fossils.
John Ray (1628 - 1705) and Robert Hooke (1635 - 1703) were
leading supporters of the theory of the organic origin of
fossils (Bassett 1971).

Sir Thomas Browne (1605 - 1682) a Norfolk man by
adoption, is perhaps the earliest recorded collector from
this area - fossil bones from his collection went to the
Royal Society and subsequently to the British Museum in
1781. Around such collections informal groups of interested
men arose and these led to the establishment of scientific
societies which had an important influence on the advance-
ment of science; they provided a nucleus around which
grew journals, museums and other institutions which provided
an essential framework for development. The Royal Society
often met in Gresham House and the Museum was catalogued in
1681 by Nehemiah Grew; it included some teeth of
Rhinoceros antiquitatis ('Woolly Rhino') presented by the
then Archbishop of Canterbury. John Woodward (1665 - 1928)
had access to these collections, as 'Professor of Physick'
in Gresham College, for his first major geological work
(J. Woodward 1695), but also formed extensive collections
of several thousand rocks, fossils and minerals in his own
right. The organisation of such a large geological
collection required careful documentation which led to the
publication of detailed catalogues (J. Woodward 1729), and
also the first exposition of 'keeping a Register of the
Fossils as they are collected' (J. Woodward 1728) which
gives advice that still holds good today.

Geological collectors and their collections can be
assessed by the importance of the person who formed the
collection, the geologists who used them, the state of
geological knowledge at the time, and the social background
that influenced whether the aim was to enhance the prestige
of its owner or aid the advancement of knowledge. It is

in this light that I look at some early Norfolk collectors.

William Arderon

William Arderon FRS (1703 - 1767) has recently
emerged as an important naturalist figure in the context
of eighteenth century Norfolk through the availability of
considerable manuscript material (Whalley 1971) which gives
an insight into how observation and collecting were applied
at this time. Arderon noted and drew fossils and a manu-
script book of such drawings from 1749 - 1757 is in Norwich
Castle Museum, together with two other manuscript volumes
once held by F. Kitton, who first drew attention to Arderon
(Kitton 1878), though lacking access to much of the material.
Arderon published some two dozen notes in the Philosophical
Transactions including several on geological subjects, but
many of his observations were published by Henry Baker FRS
(1698 - 1774) who with Martin Folkes (1690 - 1754),
President of the Royal Society, helped and encouraged
Arderon in his work. Arderon corresponded with people all
over the country and a few overseas but in the main he
studied geology by collecting and encouraging others to
send him specimens. Unfortunately there are no specimens
which can be traced back to him or his friends.

Samuel Woodward

Samuel Woodward (1790 - 1838) was a key figure in the
development of geological studies in this area. He is best
known for his 'Synoptical Table of British Organic Remains'
(1830) and 'An Outline of the Geology of Norfolk' (1833),
but a full list of his publications in a biographical paper
by his grandson (H. B. Woodward 1879) shows that his
interests included Archaeology and Natural History to a
similar extent. Like Arderon, Samuel Woodward corresponded
widely, received support from prominent men, experienced
difficulties from living in the provinces; unlike Arderon
an important part of his collection is still available for

study (in Norwich Castle Museum). Woodward corresponded
and exchanged specimens to build up his collection, and
at the same time added to the Museum collections (founded
1824) and arranged the lay-out of the geological section.
His personal collection had first call on any new
specimens with the Museum receiving duplicates. As a
convenient means of exchange or sale he made up suites of
Crag shells, mainly from Bramerton, which were well
received by institutions and collectors in other parts of
the country. His scientific letters from 1824 - 1838
comprise some 1500 items and give a useful picture of
geological thought at the time.

A major change of direction took place in the late
18th and early 19th centuries, due largely to the practical
work of William Smith (1769 - 1839) and the theoretical
studies of James Hutton (1726 - 1797) synthesised by
Charles Lyell (1797 -1875) in his 'Principles of Geology'
(Lyell 1830 - 1833). It is interesting to speculate as to
whether Woodward and his contempories were influenced by
the work of these men.

In a letter to Hudson Gurney dated 17th April 1824
(Vol 1, no. 43, N.C.M.) Woodward writes: "You having
mentioned Prof. Buckland in a former note induces me to
solicit your obtaining his opinion as to the changes
which have taken place in the outline of the German Ocean.
Prof. B. is acquainted with our Norfolk coast, he has
recently been down to examine its stratification in
company with Mr. R. C. Taylor. Geology is a science to
which I am much attached but it requires too much time
for me to make any progress. I should therefore feel
obliged if you could obtain a reasonable solution of the
changes that I have noticed as having taken place."
Gurney replied that he seldom saw Buckland and made some
of his own suggestions. Taylor's publications (R. C.
Taylor 1822, 1823, 1824A and B) and the presence of
Buckland and others in the field led Woodward to take an

excursion from July 12 - 19, 1824, visiting Yarmouth by
river from Norwich, and coastal localities from Burgh Castle
to Trimingham, observing geology and collecting fossils.
The impressions he gained are reflected in his theory on the
history of the eastern valleys of Norfolk. Woodward was
exchanging fossils freely at this time, as a note dated
February 8, 1825 (Vol.1, no. 75, N.C.M.) acknowledging his
fossils from the Yorkshire Philosophical Society shows, and
much of the later correspondence relates to the receipt or
dispatch of fossils to institutions and private collectors.

     Woodward was not always successful in his approaches
for information, as an extract from a letter dated June 19,
1825 (Vol. 1, no. 87, N.C.M.) from Taylor indicates: "...
Without wishing to discourage you from making an interesting
investigation, I must beg to decline making a transfer of
data which it has cost me many years to acquire. Such a
request appears both unusual and unreasonable. I have
certainly accumulated many notes and illustrations of the
Eastern counties, in this department, which I have been
always ready, when the opportunities occurred, to communicate
in the scientific publications..."

     Woodward made further excursions in August 1825 and
May 1826 to the north-east Norfolk coast and visited
collectors, notably the Rev. James Layton of Catfield who
had a series of Forest Bed fossils. Layton told him about
a surgeon at Swaffham with an interest in geology, Caleb
Burrell Rose (1790 - 1872). Woodward's first letter to
Rose is dated May 24, 1826 (Vol. 1, no. 109, N.C.M.) and
reads: "Sir, The Revd. Jas Layton of Catfield having
informed me that you are about to publish a work on the
Norfolk fossils, I beg to state that I have been for some
time past engaged in a similar work; situated in western
Norfolk you are undoubtedly fully acquainted with the
fossils of that district but are you alike well informed
in the fossils of eastern Norfolk? The remains of
testacea & of other animals at Bramerton are exceedingly

interesting but more particularly those of the Class
Mammalia (eight genera of which have recently been
discovered) upon our coast. I would beg to offer my
services on the work as I conceive it might render it more
acceptable by embracing the fossil remains of the whole
county. Dr. Yellowly was to have introduced me to your
notice some time since I therefore trust that my thus
addressing you will be excused & I shall be most happy in
corresponding with you on so interesting a subject."
There followed frequent correspondence between the two men
until Woodward's death, the main subjects being fossils,
the Robberds-Taylor argument and possible publications.
Rose helped with Woodward's geological map in the
delineation of the chalk divisions, though the map was
based on that of William Smith of 1819.

        Woodward and Rose took a great interest and perhaps
a certain delight in the published controversy between
Taylor and Robberds which involved the interpretation of
beds of Crag and alluvial shells in terms of the 'deluge'
(Robberds 1826, Taylor 1827A, B, Robberds 1827) and
Woodward wrote to Robberds supporting the idea of a sudden
deposition of shells due to the effects of the 'Noachic
Deluge' (Vol 1, no. 133, N.C.M.). Robberds defended his
position (Vol 1, no. 135, N.C.M.) concluding "that the
earth itself, before it was inhabited by man, passed
through a succession of revolutions, each occupying an
almost incalculable length of ages, is indisputably proved
by the clearest records of nature." Later, Woodward was
himself involved in a like debate with Edward Charlesworth
(1813 - 1893) who was supported by Robert Fitch (1802 -
1895), when Woodward ventured to assert that Charlesworth's
Red Crag was diluvial (Charlesworth 1835A) and that the
term 'Coralline Crag' was not appropriate for Ramsholt
(Woodward 1835). Fitch disputed the lack of corals at
Ramsholt (Fitch 1835) and Charlesworth vigorously attacked
the weaknesses of Woodward's argument noting that it was

based on observations made at only one visit (Charlesworth 1835B). However Woodward attempted a short reply (Woodward 1836) and Charlesworth returned to the fray (Charlesworth 1836) citing Lyell in support; "...of late my attention has been particularly directed to those views of chronological arrangement which in so comprehensive and elaborate a manner are advocated in the 'Principles of Geology'."

Why, then, did John Gunn (1801 - 1890) style Woodward, some forty years after his death, as the 'Father of Norfolk Geology'? Perhaps he had in mind that three sons followed their father's interest in geology. B. B. Woodward FSA (1816 - 1869) studied geology in his early days, as did S. P. Woodward FGS (1821 - 1865) at Cirencester and the British Museum, and Henry Woodward FRS (1832 - 1920) at the British Museum and as editor of the Geological Magazine for many years. The grandsons interests were: B. B. Woodward FLS, FGS of the British Museum (Natural History), studied Pleistocene mollusca; B. H. Woodward, Director, Perth Museum, Western Australia; Horace B. Woodward FRS, FGS (1848 - 1914) of the Geological Survey, England and Wales; H. P. Woodward, FGS Mining Engineer; and Martin F. Woodward, malacologist and biologist at the Royal College of Sciences. It is more likely that Gunn saw the 'Geology of Norfolk' as a basis for work on the fossils of the area and the subdivision of the chalk, and I believe that this was the main impact of Sam Woodward's work. The figures of fossils from his own and other collectors' cabinets included new species, so the material is still important today. Some of the types are preserved in Norwich Museum, together with a manuscript version of the 'Geology of Norfolk' which was much larger than the final production. The main differences were in size, quarto instead of octavo, the number of plates, 24 instead of 6, the number of figures, 391 in the unfinished version, with space for many more, as against 156, and the inclusion of sections of pits. The large version was never completed though much

of the drawing work was done by 1825 and the text had been
checked later by Gideon Algernon Mantell (1790 - 1852) who
greatly encouraged Woodward towards publication.

Contemporaries

.   After Woodward's death no single collector dominated
the local scene. His closest contact, C. B. Rose, began to
publish results of work in West Norfolk and is well known
for his papers on the brickearth of the Nar and his 'sketch
of the Geology of West Norfolk,'(Rose 1835 - 1836, 1865).
He followed Woodward's subdivisions of the chalk, largely
disregarded and not improved upon until 1880 (Jukes-Browne
1880). Rose formed a large collection which came to the
Museum after his death and contains figured material,
particularly species of Inoceramus (Woods 1899 - 1913). A
complete list of his papers is to be found in Horace B.
Woodward's memoir of Rose (H. B. Woodward 1893) in which
appears the comment: "his published papers.... remain of
the highest value for reference on the districts he
described."
     Richard C. Taylor (1789 - 1851), one of the first to
publish on Norfolk geology, moved his collection to London
about 1825 and emigrated to Philadelphia in 1830 where,
although he never lost contact with Norfolk, he ceased to
influence geological studies in this area. His main claim
to fame was an impressive, comprehensive work on the coal
trade of the world (R. C. Taylor 1848).
     Of the eleven collectors named in the 'Geology of
Norfolk' six had substantial collections now in Norwich
Museum - Anna Gurney, William Foulger, John King, G. R.
Leathes, C. B. Rose and Samuel Woodward. Of the others,
two from Cromer, Mr. Earl (surgeon) and Mr. Fox (lapidary),
and two from west Norfolk, Edward Edwards and Henry Hoste
Henley, little is known of their geological interests and
their collections have apparently not survived. Anna
Gurney of Northrepps Cottage formed an important early

collection of Forest Bed mammals which come directly to
the Museum. Layton's collection was mainly of Forest Bed
mammals; about 1828 he tried to dispose of it and
subsequently left Norfolk. John King's specimens only came
to the Museum in 1922, but they include valuable Norwich
chalk material from localities no longer extant.

Robert Fitch (1802 - 1895), though thought of as an
antiquarian because of his many publications in that field,
amassed a large quantity of geological specimens which came
to the Museum a year before his death. Included was a fine
series of barnacles from the Norwich chalk, described by
Charles Darwin as 'unrivalled' in his monograph (Darwin
1851). The lengthy correspondence from Darwin to Fitch
in the period 1849-51 has formed the basis of current
research (Trenn 1974).

John Gunn (1801 - 1890) formed a large collection of
Forest Bed mammalia, presented to the Museum in 1868, and
particularly in his middle and old age made many written
contributions to local geological studies; about a hundred
in all. Gunn was the most prominent local geologist for
many years and the first President of the Norwich Geological
Society from 1864 - 1877. His most extensive work was
published posthumously, edited by H. B. Woodward in 1891.

Conclusion

It is strange that the development of a 'Deluge' theory
in Britain post-dated James Hutton's condemnation of the
literal interpretation of the biblical record (Boylan 1969).
The English 'Scientific' diluvial hypothesis derived from
the teachings of Abraham Werner (1749 - 1817) and was
supported in the early 19th century by the Geological
Society of London and by William Buckland (1789 - 1856) who
influenced Woodward. It is against this background that
the early investigations in Norfolk were carried out; the
Taylor-Robberds controversy and the prevailing acceptance
of the 'Deluge' by the early collectors can be understood

in this light. The 'Deluge' theory was successfully
refuted and new ideas developed after 1840 when Louis
Agassiz (1807 - 1873), together with Buckland and Lyell,
advanced the strong case for a glacial hypothesis.

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EARTH AND LIFE SCIENCE TEACHING IN ADULT EDUCATION

R. E. RANDALL*

The sciences have been taught in Adult Education almost since further education was introduced towards the end of last century, but because many of the ideas involved are not part of everyday thought and action as in literature or history, there has always been considerable difficulty in taking the complete spectrum of the subjects to those interested to learn.

Subjects

The subjects that one can cover in earth and life science teaching in further education are legion, but the title is extremely important in connection with publicity. A poorly titled course of lectures will not attract a class of adults however interesting and informative it might be. Once a class is recruited. however, the success depends upon the method and energy of the teaching. The major factors that are noticed in successful recruitment are (i) a local element - 'The Geology of the Lake District', 'Wild Flowers of East Anglia', (ii) a personal element - 'Holiday Landscapes of Britain', 'How to Understand the Earth', 'Ecology at Work and in the Home', (iii) a modern element - 'Biosociology - a Study of Biological Sciences on Society', 'Geology Today' and (iv) a romantic element - 'Fossils', 'Britain's Best Scenery', 'Man's Place in Nature'. Courses that are merely entitled 'Geology for Beginners' or 'Ecology' rarely result in worthwhile recruitments unless the lecturer concerned is very well-known in the local area. In most cases much more thought could be given to publicity,

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both lecture title and syllabus. Where a deliberate
effort has been made, larger classes result. It is almost
certainly true that, when publicised in a lively and
interesting manner, there are no aspects of the earth and
life sciences that do not attract an adult audience.

Difficult Concepts

There is little doubt that there are difficult
concepts in the sciences that add to the difficulty of
teaching these subjects to adults without formal training.
In geology it is undoubtedly the petrological part of the
subject that suffers most severely in this respect and for
that reason it is the least commonly taught. Even crystal
formation though can be remarkably entertaining if the
necessary supporting equipment is made use of - slides,
specimens, etc. However, unless the student has a certain
amount of basic knowledge in chemistry and physics there
are bound to be steps which he cannot take. Therefore it
seems to be inevitable that in any course of lectures
which involve the use of pure science concepts, some
background information must be taught as a prerequisite
to the geology. The same difficulties hold true for
biology where it is undoubtedly the microscopic aspects
of the subject which create most learning problems.
Because the chromosome and the gene are 'invisible and
unreal' to the layman, he cannot appreciate their role
in heredity or species development. This situation can
in part be rectified by the use of 2 and 3 dimensional
models, but one of the best solutions is to attempt some
basic practical work as a class progresses, such as simple
growth experiments which stimulate the interest and aid
the digestion of the conceptual framework. It must be
emphasized at this point that in virtually every adult
education class, by the very nature of the participants,
there is bound to be a wider range of intellect than in
a comparable University or Society group, and therefore

abstract conceptual problems will be worse for some adults
than others. Due allowance must be made for the fact that
all learning is difficult, particularly in the evening
<u>after</u> a day's work has been completed, and this will be
more apparent with some students than others.

Field Work

Field work is an absolutely essential element of
teaching in all aspects of whole organism biology, ecology
and also geology. No student can have any real
comprehension of the validity of propositions made and
concepts discussed theoretically without testing them in
the field. This is particularly true for the adult student
who is only immersed in the subject for a short period
each week. Without field experience he is unable to gauge
the limits of reliability of the facts that are presented
to him in text books and lectures, and he has no idea of
the tedium and reliability (or otherwise) of data collection
unless he has experienced it in a small way himself.
Exactly the same argument applies to practical or
instrumental work in the laboratory in biology, or the
chemical and physical aspects of geology, where the adult
student is inclined to accept the written statement
uncritically unless he has experienced the difficulties
of scientific mensuration. One of the greatest
difficulties in this respect is that the majority of adult
classes take place during that period of the year which is
least suitable for field work. Excursions that take place
in the early Autumn inevitably precede the theoretical
instruction that the class will have, whereas field
classes the succeeding Summer after the Easter hiatus are
rarely well attended. In tutorial (3 year) classes this
problem does not arise because the summers can be used,
but for sessional (1 year) classes it imposes a severe
restriction on what is essentially a popular aspect of
scientific education. One highly successful answer to

field work difficulties is the Summer field week class.

Books

Suitable books for use in conjunction with adult
education lectures were for many years difficult to
obtain. However the advent of the Open University (see
this Bulletin, vol. 23) has resulted in a wealth of books
directed towards the adult student. American publishers,
too, have produced many lavishly illustrated texts in
recent years that are suitable for adult audiences, but
these have the almost insuperable problem of using North
American examples that are unknown or of no interest to
British students. One aspect of adult teaching that seems
not to be generally appreciated is the general lack of
time that most class members can devote to reading around
the subject. Only highly readable, informed texts of a
distilled nature will be tackled in depth or at length.
Therefore a great deal of care must be taken in devising
the syllabus for an adult audience. This syllabus will
bear little relation to the equivalent reading list for a
school, or higher education class, where standard texts
of the required level or journal articles can be readily
included.

Meeting Places

The difficulties resulting from unsatisfactory
meeting places for adult education classes are not limited
to the sciences, but science teaching has the added
difficulty of requiring bench space, a sink, etc. to
function fully. These facilities are rarely available
at a village primary school nor yet at the luxurious
further education centres that fully satisfy the Arts
educator. At the present time a generation of adults is
reaching the classes that have been exposed to the
sciences at secondary school in functional laboratories.
Such students find the typical meeting place facilities

particularly unsatisfactory, as, of course, does the tutor.

Teaching Equipment

A similar problem to that of meeting places is
equipment. The present-day student is no longer satisfied
with the sciences being taught with chalk and voice alone,
yet much of the equipment required, such as specimens,
microscopes and audio-visual accessories are neither
available at centres nor amenable to continued trans-
portation. This means that many of those types of
practical class that attract the adult in geology or
biology can only be held in centres where the teaching
equipment is available. In this respect the local
education provision may often be superior to that of the
peripatetic university adult educator. Nevertheless, no
amount of superior equipment or lavish accommodation can
determine a successful class. Virtually all adult
educators in the earth and life sciences seem convinced
that they can perform a successful though limited role
in virtually any material circumstances so long as they
can establish rapport with their class and kindle
enthusiasm for their subject.

This report is the result of a questionnaire sent
out to various science teachers in adult education in
Britain. I would particularly like to thank the National
Institute of Adult Education for supplying copies of
University Adult programmes and those teachers who
replied to the questionnaire.

GEOLOGY OF THE ELY DISTRICT

(largely based on work undertaken in preparation for 'The Soils of the Ely District', 1974, Mem. Soil. Surv. Gt. Br. Sheet 173)

R. S. SEALE*

Jurassic strata

The Ampthill Clay outcrops mainly to the west of the Bedford Rivers. It could not be distinguished from the Kimmeridge Clay outcropping further east. The probable position of the boundary has been sketched in near Sutton, as it has been seen at Burystead Farm, Sutton (Forbes 1969), and in Haddenham End Field (TL 459769) (Worrsam and Taylor 1969). North of Sutton the boundary is very arbitrary, being based on topography and the boundary of acid clay. The 1" Geological Survey map, no 188, shows that the Ampthill Clay also outcrops to the south-west of Stuntney. Around Manea and between Sutton and Coveney and to the west of Grunty Fen the upper part of the Ampthill and perhaps the lower part of the Kimmeridge clays are usually acid, and give rise to the Manea soil series on the skirtland, and an acid phase of the Denchworth series. This very acid clay was not found in the soil survey of sheet 188 (Hodge and Seale 1966), or on the $2\frac{1}{2}$ inch to one mile sheet TL 38 (except in one place TL 400898), either on the lower part of the Ampthill or on the Oxford clays. The pale yellow mineral jarosite, a good indicator of acid conditions, and more characteristic of the Fen Clay (see below) has been found in the solid clay, the surface of which is at about 6m (20ft) O.D. at a depth of 91-234cm in a boring at TL 47/6478, where the pH was

* Soil Survey of England and Wales, Government Buildings,
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  (published by permission of the Head of the Survey)

about 4, and at above 18 or 15m (40 or 50ft) O.D. on
possibly eroded convex sites, within the upper metre, at
TL 451804 and TL 433792. The last site near Sutton is
on a steep slope just below the boulder clay outcrop.
There appears to be a thin band of limestone at this
junction, marked by scattered rushes in the permanent
grass. Water seeps out here and the clay immediately
below is generally calcareous except in a few places over
which this water probably does not flow. Jarosite is very
common in the upper metre of the skirtland Manea series
and adjoining solid clay still covered by peat, but it is
rare in the clay above 3.7m (12ft) O.D. which was never
covered by peat. However, it may be more common below
depths of one metre on the higher ground but insufficient
deep borings have been made there.

Fossils from a cleaned ditch in Grunty Fen (TL 488769)
were probably within 9m (30ft) of the base of the
Kimmeridge Clay (Worrsam and Taylor 1969).

Whitish tabular limestone bands often occur within
the Kimmeridge Clay, e.g. in Grunty Fen (TL 553778) and
on Burnt Hill (TL 4880).

Cretaceous strata

The Sandringham Sands, and perhaps the Carstone occur
at Southery. Deposits of sand with ferruginous bands are
far more extensive than those marked as Sandringham Sands
on the old series geological maps. A boring to 275cm at
Little London (TL 628948) failed to penetrate the sand.
Derived phosphatised fossils probably consisting of
Trigonia spp. and some ammonites (Forbes 1969) occur at
the surface near the top of the hill (TL 626953).

The Lower Greensand was not always easy to distinguish
from drift deposits. The Oakington series includes soils
formed in thin drift over Greensand, as well as drift
derived from Greensand. The Cottenham series, a more
sandy soil, is more typical of the Greensand in situ.

Skertchly (1877) found a patch of Lower Greensand on the
top of Thorney Hill (TL 577793), but this was not found
during the soil survey, unless the patch marked as terrace
drift, not verified mineralogically, (TL 579791) is in
reality Lower Greensand. A small patch on Shippea Hill
(TL 620840) also not verified, has been tentatively marked
as Lower Greensand. It was difficult to decide in the area
around Great Fen (TL 6079) whether the Greensand merges
into sandy drift or not. A sample of sand collected from
a ditch (TL 625871) in Burnt Fen was found to contain much
decomposed glauconite and other minerals such as kyanite
and staurolite, characteristic of Lower Greensand (Rastall
1913, 1919, Boswell 1916, Solomon 1932, Seale 1956). A
thin layer of sandstone occurs at the bottom of this ditch.
On the other hand the heavy minerals in a sand sample
nearby, rather higher up the slope, where flints were more
common, (TL 628872) were found to be typical of the drift
deposits, there being much garnet, with relatively little
kyanite and staurolite and no glauconite. The Gault is
largely hidden by fen deposits. The junction with the
Greensand can be seen in cleaned ditches at Castles Farm
(TL 560775) (Forbes 1969). It forms a distinct ridge
(TL 6487) alongside the Little Ouse River north of Shippea
Hill station. Near Stuntney the Gault is about 27m (90ft)
thick but it thins north-eastwards to about 20m (65ft) in
Joist Fen (TL 6986) where the junction with the Chalk Marl
lies about 24m (80ft) below the surface of the ground
(Essex River Authority boring). The Lower Chalk forms
relatively low-lying mostly rather hummocky ground, except
in the north-east where it rises abruptly from the edge of
the Fens in two places. Much of it consists of Chalk Marl.
The Totternhoe Stone has been traced from Weston Ditch
(TL 6777) to Beck Row (Jukes-Brown and Hill 1887) and is
exposed in the quarry near Blackdyke Farm (TL 690886)
(Peake and Hancock 1961). In Shepherds Fen (TL 6985) peat
over sand, extending to depths of about 2.5 to 3.8m ($8\frac{1}{2}$ to

$12\frac{1}{2}$ft) lies over about 21m (70ft) of Chalk Marl (Essex
River Authority borings).

Quaternary deposits

The Chalky Boulder Clay occurs on many of the Fen
Islands and extends into the Fens beneath the peat and Fen
Clay in several places in the north-east. It also occurs
at a low level south-west of Stuntney (TL 5476). In Fodder
Fen Common (TL 492933) the top of the boulder clay was
encountered at about -3.3m (-11ft) O.D.

It is possible that Grunty Fen, which is almost
completely enclosed by higher ground, originally drained
eastwards into the Cam-Ouse system, and that the outlet was
blocked by boulder clay. The present outlet is relatively
steep-sided and cuts through the boulder clay in the north.
There is a smaller enclosed fen west of Chettisham
(TL 5483) with a similar steep-sided narrow outlet cutting
through the boulder clay in the north, but without any
other obvious pre-boulder clay outlet.

The distribution of the March Gravels shown on the map
is largely based on the work of Baden Powell (1934) taking
also their height above sea level into consideration. Near
March they are very fossiliferous, but further south they
grade into the terrace deposits and are sometimes difficult
to separate from them. At Stonea the fossiliferous gravel
was seen to overlie chalky boulder clay in the cutting of
Harding's Drain (TL 45932). The March Gravels are now
believed to date from the last or Ipswichian interglacial
(Stevens 1960). Baden Powell found that they are overlain
in many places by up to nearly 2m (about 6ft) of 'brickearth',
which is a sandy clay, sometimes stony but never laminated.

River-terrace sands and gravels, over 3km wide, extend
southwards from Stonea. They are at a lower level than the
March Gravels, but merge laterally into what are probably
unfossiliferous March gravels at above 3.7m (12ft) O.D. on
Honey Hill (TL 435885) and Langwood Hill (TL 415850).

In the south the surface lies mainly between about 0.6 and
1.8m (2 and 6ft) O.D., but in the north the deposit is
covered by peat and is mainly below sea-level. All over
its outcrop there is generally an upper fine sandy loam
layer, often over clay loam, passing down into calcareous
coarse sandy loam and gravel which can be chalky. Together
with some small isolated patches of low-lying sand and
gravel south-west of Mepal this spread probably forms part
of the terrace system near Earith which has been mapped as
the first and second terraces of the Bedfordshire Ouse
(Edmonds and Dinham 1965). A section (TL 389579) showed
over 3m (10ft) of bedded chalky gravel overlain by 30-120cm
(1-4ft) of brown flinty loam, which, due to extensive
pitting, extended into the gravel as irregular pockets
(Edmonds and Dinham 1965). Organic material in these
terrace deposits near Colne, about 5km south-west of Sutton
have been shown to be about 42,000 years old so proving a
Weichselian age for these deposits (Bell 1970). The
terraces are also related to the extensive first and second
terraces near Cambridge, the upper (intermediate) terrace
being of early Weichselian age (Lambert et al. 1963). The
upper layer of fine sandy drift, a few inches thick, so
widespread over coarse terrace deposits, and lying directly
under the peat in many areas, is evidently equivalent to
the 'brickearth' which Baden-Powell (1934) found above the
March Gravels. This is perhaps of wind-blown origin.

In many places on the terraces (e.g. TL 4383) aerial
photographs show a polygonal pattern indicating variation
in plant growth, especially sugar beet, in dry summers.
The polygons are often about 50-100m across, their edges
evidently representing old frost cracks in predominantly
loamy or sandy soil, into which fine textured material has
been washed down. Crops growing directly over the old
cracks are therefore less liable to suffer from drought
than those between. A similar pattern has been
photographed in the terrace deposits about 4km south-west

of Sutton just beyond the border of the map (West 1968).
Small patches of low-lying terrace deposits occur in many
places. At Shrubhill (TL 660880) they consist of coarse
sub angular flinty gravel in a sandy matrix over sand
(Prigg, in Whitaker et al. 1893) altogether about 3.7m
(12ft) thick with the surface only 1.8m (6ft) above the
level of the river (Flower 1869). Skertchly (1877) found
low-lying deposits, superficially like weathered Lower
Greensand, at the north-east ends of Thorney Hill and
Stuntney island respectively, which he believed to be
river-drift or perhaps rain-wash deposits. The Stuntney
site was not identified but the Thorney Hill sand
(evidently TL 577795) was investigated microscopically,
and the heavy minerals were found to be typical of the
drift. Heavy minerals were also investigated from other
sites, several of them at higher levels (e.g. near Little
Downham, TL 522843, 531840, 535838, 543838, and Burnt Fen
TL 613882, 618876), which proved to be from drift and not
Lower Greensand.

Much of the Chalk in the east and south-east is
covered by coarse sandy drift, sometimes gravelly, which
extends into the Fens. This drift is similar to, and
continuous with that in the Brecklands. A characteristic
feature of this area is the 'hills and holes' micro-relief.
This is especially well developed on the sandy drift of
Mildenhall and Hockwold Fens, and is also characteristic
of the low-lying chalk regions. It has been described in
general by Sparks et al. (1972), to the south of the mapped
area by Hodge and Seale (1966) and Worrsam and Taylor (1969),
near Eriswell (TL 7179) by Perrin (1966) and in parts of the
Brecklands by Corbett (1973). On the low chalk mound at
Kennyhill (TL 6780) the hummocks are undulating, often
discontinuous, chalky ridges up to 1 metre high, which
contrast with the deeper rather darker soil between when
the land is ploughed. Towards the north-east (TL 6981),
where the ground, ranging between 1.5 and 4.8m (5 and 16ft)

O.D., is rather higher, the oval or circular hollows range from about 50-200m across, with a maximum vertical dimension of about 2.75m but they are less distinct higher up. On the sandy drift the hollows are filled with peat, peaty loam, shell marl, or sand, or mixtures of these. The surface of the hollows is often 2m below the tops of the ridges and the peat infilling can extend down a further 2m or more. The hollows are often about 50m across. Many are smaller, though occasionally they are up to 500m long and 150m wide. Sometimes they are completely obliterated by blown sand. In Hockwold Fens especially, only the tops of the sandy ridges may appear above the level of the peat fen, while in parts of Feltwell Fens the presence of hummocky ground may only be detected by differences in the depth of the peat. In one place (TL 6890), although the surface is level, the peat over Chalk Marl ranges in depth from about 0.6 to nearly 2m over short distances.

High level sands and gravels of uncertain age occur on the summits of several of the Fen islands. Near Sutton (TL 450795) the deposits may be of glacial origin. Other deposits, possibly representing high terraces, occur on sloping ground (TL 440785, 443765, 446817). In two places close to the main river banks the possible terrace deposits have not been checked by boring (TL 580840 and 577863), although the surface appeared sandy and rather gravelly.

The main rivers probably flowed in almost constant courses from the retreat of the ice until historical times. The final channels before diversion are now represented by old ways, roddons or old runs (Fowler 1932, 1933, 1934A and B).

Detailed sections of the lateral relationship between the main river channels and the 'backwater' area have been made near Ugg Mere between Huntingdon and Peterborough (Godwin and Clifford 1939), at Shippea Hill (Clark 1933, Godwin and Clifford 1939) and Old Decoy Farm (Jennings 1950), the latter data concerning the Little Ouse being

supplemented by Soil Survey work. Sections of the Little
Ouse roddon, about a mile apart, which show a complicated
history of erosion and deposition, were investigated at
Plantation Farm, Shippea Hill (TL 644848) and Old Decoy
Farm (TL 658853). The immediate post-glacial channel of
the river was about 1.5 to 3.4m below the general level of
the fen floor. It was bounded by sand banks about 180 to
300m apart and rising 1 to 3m above the fen floor. These
sand banks were occupied by man in Mesolithic, Neolithic
and Bronze age times (Clarke 1933, Clark et al. 1935,
Godwin and Clifford 1939 and Godwin 1960). The sand stands
up above the peat in several places (TL 627847, 613843,
636854, 639848, 659856, etc.). The other main rivers
flowed in comparable deep channels. One, along the old
course of the Cambridgeshire Ouse, was proved at Prick-
willow railway bridge, and (on Sheet 188) at Dimmock's
Cote road bridge, where firm foundations on the Kimmeridge
Clay floor were not found till depths of about 10m (42 and
40ft respectively) had been reached, whereas nearby the
clay is usually not more than 3.7m (12ft) down (Fowler 1934
A and B).

Peat assigned to pollen zone IV (Godwin 1940) was
formed in the deep river channels before about 7500 BC
(Godwin 1960), but it does not appear to have spread over
the greater part of the fen basin much before 3000 BC
(Willis 1961), though Godwin and Clifford found peat dating
before 5000 BC at Queen's Ground, Methwold Fens. The
peat is thickest in Joist Fen (TL 6986) and Isleham Fen
(TL 626765) in the ancient channels of the Little Ouse and
Lark respectively. Thick peat also occurs north-east of
Sam's Cut Drain in Methwold Fens and in parts of Feltwell
Fens, east of Cross Bank, where the land has only recently
been adequately drained. Moderately thick peat also occurs
north-west of Ely in Padnal Fen, between Ely and Stuntney
in Middle Fen, in parts of Mildenhall Fen, in North Fen, in
the Bedford washes and in a few small places west of the
Bedford Rivers.

The <u>Lower Peat</u> lies beneath the Fen Clay on the
mineral floor of the Fen. Beyond the limits of the Fen
Clay it passes imperceptibly into the Upper Peat and its
upper limit cannot be distinguished in the field. In the
central regions few borings penetrated the Lower Peat, and
it appeared from this limited evidence that the Lower Peat
is seldom much more than a metre thick in the Cambridgeshire
Ouse Basin, thinning out to 0.1m in places, even in the
central regions (e.g. TL 557934). It is up to 1.5 metres
thick in the basin of the West Water in the south-west and
to the south of March. Further west, between Benwick Mere
and Warboys, Hunts, this thickness appears to be maintained
in this basin over wider areas, even near the southern
boundary of the Fen Clay. Apart from some Boulder Clay in
the north-west, Jurassic and Gault clays, generally with a
thin(?) sandy covering, appear to underlie the Lower Peat
over the deeper parts of the Fen Basin around Ely.

The <u>Fen Clay</u> marine transgression began about 3000 BC
in the north and was apparently at its maximum at about
2,250 BC when it extended as far as Wood Fen north of Ely.
Willis (1961) states that this phase ended here at about
2,200 BC and was completed in the north at about 2,000 BC.
He suggests that at any particular place 300 or 400 years
of Lower Peat formation preceded the clay deposition. The
peat covering the Fen Clay has now largely disappeared
revealing the network of roddons over it. The majority
appear to be contemporaneous with, and their deposits merge
into, the Fen Clay. The roddons form a dichotomous network
similar to the creek pattern found in present day salt-
marshes, and it seems probable that the Fen Clay was formed
in this manner. The deposit is unconsolidated, and wedge
shaped in vertical section, being thickest in the north and
thinning out towards its edges in the south. Sometimes
there are interdigitated layers of peat within the Fen Clay
near its margins, but often the edge is more abrupt. South
of Butcher's Hill (TL 5390), Fen Clay 2.6m thick was found
within 100m of its margin. In places, instead of thinning,

the clay may gradually become more organic with increasing
reed-remains towards its edge. It extends for some
distance up the main river channels. Few borings
penetrated the Fen Clay in its central regions. In
Cranmoor Lots (TL 491933) it is about 2.4m (94in) thick on
about 0.15m (6in) of Lower Peat over Boulder Clay. In
Burnt Fen (TL 592875) 3.6m of Fen Clay lies on 1.5m of
Lower Peat on a sandy substratum.

The roddons, with their calcareous silty deposits
largely thin out towards the boundaries of the Fen Clay,
and where the top of the Lower Peat is above the water-
table and the Fen Clay is thin, it is generally very acid
and contains jarosite or natrojarosite $(KFe_3(SO_4)_2(OH)_6$
and $NaFe_3(SO_4)_2(OH)_6)$ (Brown 1960, Soil Survey Staff 1960).
These minerals also occur in those parts of the substratum
above the water-table. Jarosite is present in thicker Fen
Clay, though much less commonly. In the Fens it appears
to have formed since drainage.

The Upper Peat was formed over the Fen Clay but much
of it has wasted away. It is still 2m or more thick north-
east of Southery and within the Bedford wash, where it is
preserved by a covering of alluvium. It exists beneath the
Romano-British silty alluvium north-west of Welney where it
is generally about 75cm thick, though ranging between about
40 and 140cm thick.

The Old Fen Meres were shallow lakes in the marshes,
usually no more than 60-90cm (2 or 3ft) deep, in which
shell (or Chara) marl was deposited. Redmere was the
largest of these lakes, with shell marl about 1 metre thick
over most of its area. Another lake 'Lesser Redmere'
(TL 635875) appears to have been ponded against the present
banks of the Little Ouse. Here the marl varies from about
20-60cm thick, over 15-90cm of Upper Peat, 15-70cm of Fen
Clay and about 15-30cm of Lower Peat, over the sand or
sandy clay loam of the fen floor at a total depth of about
2.1 to 2.4m. A distinct channel therefore cuts through the

ridge on the south-west side of the Little Ouse. In
Feltwell Fens a considerable area of shell marl, 25cm to
over 1m thick, still has a covering of peat. Smaller
shell marl patches under a layer of peat occur in
Mildenhall Fen. Redmere itself is mostly beyond the limit
of the Fen Clay. Here shell marl lies over about 2-2.35m
of peat in the north, thinning to 60 or occasionally as
little as 25cm in the south. Patches of shell marl are
common to the east of the old Cambridgeshire Ouse and
between the old river and the high ground of Ely and
Littleport and to the north of Littleport, but very rare
to the west. Thin shell marl does occur associated with
the West Water, the course of the old Huntingdonshire
Ouse in the south-west, but these deposits are mostly
covered by about 30cm or so of humose alluvial clay
believed to date from 180 AD (Coles and Liversidge 1965,
Worrsam and Taylor 1969 and Salway et al. 1970).   One
minute isolated patch of shell marl occurs near March
(TL 436945).

Apart from Harrimere (TL 536766) none of the meres
appear on any of the maps, unlike those further south and
west, and no records exist about them. On a hillside
south of Ely (TL 535792 and 540796) there are two small
deposits of silty clay loam with freshwater shells which
fan out onto the flatter ground below. These probably
mark the site of springs. A rather similar deposit occurs
on flatter ground on the river terrace (TL 417849) where
there was evidently a pond.

Some watercourses, beyond tidal influence, are now
marked by a shell marl called old slades (Fowler 1934A),
there are a few of these associated with the River Lark
and its diversions and one north of Shippea Hill.

River Clay   occurs in the south-west associated
with the West Water. It is generally between about 30
and 50cm thick and lies over about 60-90cm of Upper Peat.
It is a very fine deposit, sometimes with over 90 per cent

clay ($<2\mu$ e.s.d.) and it extends to the south where it is often thicker (Edmonds and Dinham 1965, Worrsam and Taylor 1969). Clay or silty clay has also been deposited by floodwater near Ely (TL 5781), between the embankments of the modern rivers and in parts of the wash between the Bedford Rivers. This wash was formed in 1650 when the New Bedford River was constructed. The maximum depth of the clay is now 60cm near the south-western end, but 20-30cm is a more general thickness. The clay thins across the wash towards the Old Bedford River.

The estuarine silts of the Romano-British marine transgression occur at Welney, and extend up the old courses of the Cambridgeshire Ouse and Little Ouse and up Darcy Lode in the north-west. A study of the foraminifera in the silt proves their marine or estuarine origin (Macfadyen, in Godwin 1938). Apparently, in contrast to the rather lobate form of the earlier Fen Clay transgression, the deposits in the tidal creeks extended beyond the main deposition areas, with peat formation between the levees of the larger watercourses, which must have stood out above the general level of the marshland as in the present day north-west German marshes, where the raised silt land is called 'Hochland' and the intervening peat land 'Sietland' (Godwin 1938). The calcareous silt, which stands up to 3m (10ft) O.D., changes laterally into the adjoining peatland through a fringing zone, sometimes up to 500m wide, of humose non-calcareous clay, sometimes containing jarosite, perhaps representing an area where a very slow tidal flood, carrying suspended clay, percolated into a peat-forming vegetation. This fringing zone, becoming narrower upstream, borders the old courses of the Cambridgeshire Ouse and Little Ouse, its acidity contrasting strongly with the calcareous silts of the roddon ridges. North-west of Welney and in Upwell Fens the ground surface is very uneven. The Old Croft River on the

county boundary follows along the course of the old river
with high silt banks on either side. Beyond these banks
there are irregular or rounded depressions often 2 or 3m
deep, of all sizes ranging up to 200m or more across. The
soil in these hollows is almost invariably of finer texture
than that higher up. It seems probable that the fringing
clay deposit described above extends beneath much of the
estuarine silt and is exposed in the deeper hollows. This
layer, separating the silts from the Upper Peat beneath,
is generally about 20-60cm thick. It does not extend under
Darcy Lode or the main river channels, where the silt
deposits cut into both Upper Peat and Fen Clay. On the
other hand the clay may represent a period of freshwater
flooding contemporaneous with that associated with the West
Water in the south-west. A study of the foraminifera would
probably throw light on this problem.

        The River Lark was evidently diverted in Roman times
(Fowler 1934A), before the extensive silting-up of the
canals which branched off the old Cambridgeshire Ouse and
now stand up as distinctive roddons. One of these canals
joined the Ouse a short way above the Old Lark and its
roddon is much higher and more distinctive than that of the
Lark. West of Chatteris the estuarine silts did not
penetrate nearly as far up the West Water.

        Groups of short parallel roddons occur in the north,
standing up to 2m or so above the surroundings (TL 4795,
4895, 5194 and 5394). They are probably silted-up Roman
drainage ditches; the least disturbed group (TL 5394) is
within the Bedford wash (Astbury 1957, Salway et al. 1970).

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MAP OF THE GEOLOGY OF THE ELY DISTRICT
(largely based on work undertaken in preparation for 'The
Soils of the Ely District', 1974, Mem. Soil. Surv. Gt. Br.
Sheet 173)
R. S. SEALE*

      This map is issued with Bulletin No. 25 of the
Geological Society of Norfolk on a separate A3 sheet at a
scale of very approximately 1:75,000.

      A master dyeline copy of the draft map on a scale of
1:63360 (1" to the mile) is held by the Cartographer,
School of Environmental Sciences, University of East
Anglia, Norwich NOR 88C. Dyeline copies of this draft
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Reference

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* Soil Survey of England and Wales, Government Buildings,
    Block B, Brooklands Avenue, CAMBRIDGE CB2 2DR
    (published by permission of the Head of the Survey)

Quaternary	Flandrian	∿	River Clay	
		☥	Shell Marl	
		∿	Peat	
		ez	Estuarine Silt (Romano-British)	
		ec	Estuarine Clay (Romano-British)	
		━	River Deposits (Bronze age to early Romano-British)	
		fc	Fen Clay	
	Devensian	0	Low-lying Sands (Coversand?)	
		1	First Terrace ?	River Gravels
		2	Second Terrace ?	
	Ipswichian	≈	March Gravels (Marine)	
	Wolstonian ?	≋	High-level Gravels	
	Anglian	▽	Chalky Boulder Clay	

Unconformity

Upper Cretaceous	Cenomanian	h 5a2	Upper Beds	Lower Chalk
			Totternhoe Stone	
		h 5a1	Chalk Marl	
Lower Cretaceous	Albian	h 3-4	Gault Clay	
	Lower Albian & Aptian	h 2	Lower Greensand	
		h 2c	Carstone	
Lower Cretaceous/Upper Jurassic ?		h 2s	Sandringham Sands	

Unconformity

Upper Jurassic	Kimmeridgian	g 12	Kimmeridge Clay
	Corallian	g 11e	Ampthill Clay

▦	*Built up areas, quarries, airfields & other disturbed ground*
———	*Geological boundaries*
·······	*Geological boundaries beneath one superficial layer*
-------	*Geological boundaries beneath two or more superficial layers*
— — —	*Peat boundaries*

Key to Map of the Geology of the Ely District

SECRETARY'S REPORT FOR 1973

There were seven lecture and demonstration meetings in 1973. January 'Demonstration of techniques', at the School of Environmental Sciences; February, Mr. I. Richardson, 'The Hydrogeology of Norfolk'; March, Mr. J. Goff, 'On some aspects of the Catton Sponge beds'; April, 'Members' specimens'; October, Mr. B. McWilliams, Presidential Address 'The Place of Early Collectors in the development of Geological Studies in Norfolk'; November, Mr. P. Cambridge, Professor B. M. Funnell and Mr. N. Peake, 'The Geology of the Norwich Area - A Review'; December, The Annual General Meeting, followed by a showing of the film 'When Polar Bears Swam in the Thames'.

There were three Committee Meetings during the year.

1973 was my first year as Secretary following the retirment of Mr. B. McWilliams. This report therefore gives me the opportunity to express, on behalf of the Society, our thanks for all that Brian McWilliams has done for the Geological Society of Norfolk during his tenure of office, an important period in the Society's history. On a more personal level I should also like to thank him and the rest of the Committee for the help given to me in the somewhat daunting task of following in his footsteps.

A new Secretary taking over at the beginning of the year has the advantage of a Winter Programme already prepared. However, the new year was marked by a change in venue in that lecture meetings moved to the University. This has the disadvantage of relative geographical remoteness in that it is on the outskirts of the city and not, like the Museum, centrally placed. However, it is heartening to see that members have not found this too much of a barrier and attendances at meetings have remained at an encouraging level.

Following circulars to members to solicit opinion it was decided to transfer meetings from Thursdays to Mondays. This was first carried out in November.
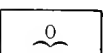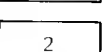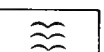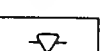
Membership has continued to grow steadily and in general the GSN is in a healthy state. That it should continue to be so depends largely on the Committee being able to provide a stimulating programme of lectures, field meetings and publications. I should be grateful, therefore, if members would always feel free to contact me either at meetings or in writing if they have any suggestions on any aspect of Society business.

January 1974   Christopher J. Aslin

Key to Map of the Geology of the Ely District

		~	River Clay
		⟨Shell Marl symbol⟩	Shell Marl
		~	Peat
	Flandrian	ez	Estuarine Silt (Romano-British)
		ec	Estuarine Clay (Romano-British)
			River Deposits (Bronze age to early Romano-British)
		fc	Fen Clay
Quaternary		0	Low-lying Sands (Coversand?)
	Devensian	1	First Terrace ?
		2	Second Terrace ?
	Ipswichian	≈	March Gravels (Marine)
	Wolstonian ?	≈	High-level Gravels
	Anglian	⟨symbol⟩	Chalky Boulder Clay

Devensian River Gravels span First Terrace ? and Second Terrace ?

Unconformity

Upper Cretaceous	Cenomanian	h 5a2	Upper Beds
			Totternhoe Stone
		h 5a1	Chalk Marl

Lower Chalk spans Cenomanian beds.

Lower Cretaceous	Albian	h 3·4	Gault Clay
	Lower Albian & Aptian	h 2	Lower Greensand
		h 2c	Carstone
Lower Cretaceous/Upper Jurassic ?		h 2s	Sandringham Sands

Unconformity

Upper Jurassic	Kimmeridgian	g 12	Kimmeridge Clay
	Corallian	g 11ᴾ	Ampthill Clay

⟨dotted box⟩	*Built up areas, quarries, airfields & other disturbed ground*
———	*Geological boundaries*
· · · · · ·	*Geological boundaries beneath one superficial layer*
- - - - - -	*Geological boundaries beneath two or more superficial layers*
— — —	*Peat boundaries*

ELY

© Rothamsted Expt.

0   1   2   3

0   1

3   4   5   6   7   8   *kilometres*

2   3   4   5   *miles*

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BULLETIN OF THE
GEOLOGICAL SOCIETY
OF NORFOLK

No. 26

CONTENTS INCLUDE:

The nature and assessment
of Fieldwork in geology

Hunstanton fossils

FIELDWORK ASSESSMENT SPECIAL ISSUE

EDITORIAL

        This edition is largely devoted to a seminal article
on the nature and assessment of fieldwork in geology by
David Thompson of the Department of Education at Keele
University. Mr. Thompson holds the first appointment at
an English university in geological education, and is there-
fore well equipped for this task. It is hoped that this
article will be widely read, and I will gladly consider any
comments or rejoinders from readers.

        The growing importance of geology as a school subject
has been seen in previous articles in this series, and I
think that Mr. Thompson makes a good case for the key
importance of fieldwork within syllabus study. His article
should certainly be given to head teachers who have doubts
about allowing time and funds for its pursuit.

        There is only a little room left for our other item,
a note from Hamon Le Strange, well known for his collecting
in the Hunstanton district and his generous help in hiring
an excavator for fieldwork on Hunstanton beach. More of his
material can be included at a later date.

        Bulletin No. 27 will be issued in April 1975. Contri-
butions should be sent to me as soon as possible and no
later than December 31, 1974.

        Will contributors please note that manuscripts are
acceptable in legible handwriting, although typewritten
copy is preferred. In either case it would be a great help
if details of capitalisation, underlining, punctuation, etc.,
in the headings and references (particularly) could conform
strictly to those used in the Bulletin. Otherwise
publication may be delayed.

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Thick lines, close stipple, or patches of black are not acceptable, as these tend to spread in the printing process employed. Original illustrations should, before reproduction, fit into an area of 225 mm by 175 mm; full use should be made of the second (horizontal) dimension, which corresponds to the width of print on the page, but the first (vertical) dimension is an upper limit only. All measurements in metric units, please.

R.S.J.

THE NATURE AND ASSESSMENT OF FIELDWORK IN GEOLOGY

D. B. Thompson*

1. Introduction

In conversation, teachers of geology at all levels (CSE, O, A and university) indicate that they regard the doing of fieldwork to be the basis of the study of the subject. Hence even at school, teachers are keen to take their students into the field despite the difficulties of finance, distance to outcrops, loss of holiday time, disruption of the school programme, the risk of incurring the odium of colleagues (some of whom regard all trips outside school as 'play'), and the need to enlist the services of another member of staff. Are they right in wanting to do fieldwork?

Often it is apparent in conversation that school teachers, even some university teachers, are not clear about what they should do, or why they should do what they do, in the field (see for example University of London geology conference, 1973). This may be because some school teachers have little geological background and no training in teaching science. Often schoolteachers with geographical training may, or may not, wonder how geological fieldwork should differ from geographical. What should be the nature and purpose of geological fieldwork at CSE, O and A level?

A great number, however, who know their minds, are keen to have fieldwork assessed because they say it is so important (e.g. in an 'A' level survey: Thompson, 1969). In that study some teachers wished to have a considerable percentage of marks set aside for the assessment of field-

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* Department of Education, University of Keele, KEELE, Staffordshire ST5 5BG

work, but they were unclear as to how the assessment
procedure should be devised. Should the fieldwork be
treated as a piece of project work as in many CSE
subjects and university mapping theses? In any case by
what criteria should it be assessed?

By far the greatest amount of fieldwork is carried
out during university courses. Does their procedure
commend itself to schools? Surprisingly few manuals
exist which discuss or detail the skills concerned in
fieldwork at this level and most of these are rather
dated and mostly concerned with field mapping (Geikie
1900, Grenville-Cole 1903, Willis 1923, Greenly and
Williams 1930, Lahee 1961, Kottlowski 1965, Harpum 1973).
Himus and Sweeting (1951) is the only work which could be
said to be suited to school use. Most university training
is accomplished by group, or rarely personal tuition,
often by personal example, followed by practice on
relatively uncharted ground at distant places, often
abroad. Traditions vary enormously. In most cases at
university level the teaching of fieldwork skills is not
assessed directly except by marking a mapping thesis. It
is interesting in this context that in the last few years
Oxford University have had one finals paper taken in a
hitherto unvisited quarry wherein students can be observed
and assessed in all that they do, by both internal and
external examiners. Their mapping thesis is treated as a
separate exercise. None of these procedures could be
easily translated in their entirety to the school
situation.

2. Should fieldwork be undertaken?

Considering how little fieldwork is emphasised in
official syllabuses (see Tables 1, 2, 3) the literature on
the virtues of geological fieldwork in education is
surprisingly strong. Quotations will suffice to give an
indication of the high position in which fieldwork has
been regarded:

<u>British Association for Advancement of Science</u> (1937, p.283) "Geology taught without proper regard to the phenomena which the pupil can observe and study for himself must become dull and unreal."

J. Platt (1946, p.20) "Any attempt to neglect the practical and out-door aspects and to teach the subject in any other way will be doomed to failure ... Moreover, it will follow that his scholars, being likewise obliged to depend upon the observations of others, will soon become quite content to do so, and thus the teaching will fail in its object to train the powers of observation, the whole value of its training in scientific method will be lost and the chief objects of its inclusion in the curriculum will be frustrated."

(p.18) "The subject supplies ample scope for true scientific training, training in observation, in the investigation of observed facts, in the testing and applying of inferences, and in their interpretation and classification."

V. Wilson (1947, p.4) "Secondly, I cannot plead too strongly that any programme of instruction in geology in schools must at all times stress the pupil's experience in both the subject matter and method of science. Early every-day experiences if not rationalised into knowledge soon become evanescent as the child grows older. His restless observation should be encouraged and made as accurate and complete as possible, and only when his acquaintance with geological phenomena is becoming tolerably exhaustive should he be introduced to the new sources of information which our textbooks supply. In teaching geology we must not put theories, definitions, rules and principles first, but disclose them as they come in the order of nature through the study of examples."

J. Greensmith (1958, p.107: re Secondary Modern Schools) "Whenever possible, the pupils should be allowed to construct their own clinometer from a protractor and in provided notebooks encouraged to accurately record pertinent information. Moreover, the drawing of simple sketches showing the main geological features exposed at various localities should be attempted. An estimate of the thickness of beds exposed is usually possible and, if conditions are favourable, the more able can accurately measure bed thickness by tape or rule, or by using simple trigonometrical methods. Finally, the idea can be put forward that junctions between beds (or groups of beds) can be reasonably accurately followed by the use of exposures, topography and soils. With the teacher's assistance it may then be possible for the pupils to plot more obvious junctions in the local rocks on to the Ordnance Survey map, thus building up a local geological

map.   Naturally this process will, and indeed should, take time and may prove impractical for many reasons."

(1965, p. 482:   re C.S.E.) "The basis of the syllabus, and its attendant examination, is as far as possible the immediate school area.   The pupils should be encouraged to inspect the local rocks and scenery as much as possible despite timetable disorganisation."

George et al. (1967, p.65:   re Secondary Modern schools) "... geology only comes to life when the pupil himself becomes a geologist ...   Geology then is an intrinsic part of field study and the end of the teaching exercise is to give the pupil some understanding of the geological processes and products he himself has seen.   Excursions, therefore, should form an accepted, central part of the teaching of geology, and should indeed be the peg upon which geology hangs.   ... insufficient concern with processes may result in the pupil's failing to understand the significance of the products as he sees them in the actual rocks and in the specimens he collects in his own neighbourhood."

Bradshaw et al. (1970, p.77:   re O level) "Geology should therefore provide the student with training and experience in observation, measurement and interpretation; ...   The emphasis placed on a scientific approach to geology is important.   ...   Field-work is the only way in which the full evidence available can be appreciated, and should form an important component of the course."

Bassett's address (1971), much quoted elsewhere in this article, clearly supports the case that fieldwork should be given greater prominence.   Perhaps the literature has been overlooked.   Perhaps the teachers have not had access to it, or if they had, they may not have drawn the attention of the Boards to the recommendations.   Perhaps the Boards did not listen or did not have antennae to receive the comments available.   The possibilities are endless and speculative, but herewith is a verbatim quote from a report which dealt with A level and was based upon replies from nearly 20% of the membership of the Association of Teachers of Geology.   This may dispel some speculations.

Thompson (1969, p.9 - 10:   re A level) "Fieldwork . The time given to fieldwork at A level was as follows (in days):

YEAR	MEAN	MAX	MIN
1	5.93	20	0
2	5.36	15	0
3	6.70	11	0

General comments. One Cambridge member said that fieldwork was not really required, another that boys were not available at weekends and classes could not be disturbed during the week. London and J.M.B. members thought fieldwork was inadequately examined and that examinations could be passed without real fieldwork. Guidance was needed by some on the type of fieldwork to be done. Others thought it wrong that London teachers should grade the fieldwork of their own pupils: they wanted an examiner to mark it. One thought it should be an option. One Northern member requested an oral examination, another a compulsory question. One Oxford school reported that only solving of simple maps was required and suggested that more questions should require field knowledge.

Mapping and detailed measurement. Several London members encouraged their pupils to make geological maps and measure sections, sometimes the latter as an alternative to the former. Many J.M.B. schools did such work. One member asked that simple mapping be included in the syllabus, since students enjoyed the freedom and responsibility of the exercise. Another suggested that it was appropriate only for the 3rd year sixth since it took so much time. One Oxford and Cambridge school mapped and measured: another did not. Welshmen noted that nothing was specified in the syllabus, that work varied with the enthusiasm of candidates, that more could be done. One said that the measuring habit was essential.

Cook's Tour geology. Most agreed that some of this work was useful early in the course in order to increase awareness and regional experience. It was said, in moderation, to be an excellent method of teaching (L). Other members disapproved heartily (C, N), but noted that this kind of work adequately covered examination needs and was therefore the only type done. In Wales this work, coupled with sample study and sketch maps of photographs, appeared to be the main experience sought."

At the end of the report (p.11) some recommendations were made by teachers. They asked that:

"(e) A means be devised of examining fieldwork

     (L, N). The type of fieldwork required

     should be stated clearly in the syllabus.

 (s) Field techniques be emphasised."

[C = Cambridge Local Board   L = London Board   N = Joint
Matriculation Board]

     A damper is provided by Paling (1969, p.5):

"Unfortunately the idea has grown up amongst some teachers
that the only geology worth doing is that which is carried
out ·in the field. Nothing can be imagined more likely to
antagonise the average headmaster. From his standpoint,
subjects suitable for the curriculum must fit into thirty-
five or seventy minute periods in the classroom; regular
afternoons off for "frolics in the country" are
unthinkable. It is certainly true that pupils should
visit quarries and other places where rocks can be examined
in situ and specimens collected. Such excursions, however,
can be arranged at the end of term or other convenient
times. Some interested pupils are prepared to carry out
fieldwork in their own time and seem able to persuade
parents to provide transport. In any case it would be a
very restrictive course which dealt only with local
geology."

     Despite the last comment, there is every reason to
treat fieldwork as the one aspect of geology that is most
basic and hence to have pupils do it whatever the odds.

3.   Fieldwork in present school syllabuses
(i)   Introduction
     A review of the demands made by syllabuses and the
guidance given by CSE and GCE boards reveals that much is
unclear and unspecified. Except in odd cases teachers do
not have much clue as to what is 'officially' expected.
The wording of passages which refer to fieldwork is often strong
only   in the sense that it indicates an obligation or
near obligation to do some. The passage is often framed in
a manner which suggests that it can be used as a stick with
which to beat an uncomprehending headmaster or LEA when
funds are needed to support fieldwork. But what kind of
fieldwork? It is assessed? If so, by what criteria?
(ii) Present arrangements
     The following tables (Tables 1, 2, 3) give an
indication of the arrangements. Only the Associated
Examining Board and the Welsh Joint Education Committee

put fieldwork at the beginning of the syllabus and treat
it as a priority.   Others mention it and tuck it away,
often in the middle or at the end of the syllabus, in as
few words as possible.

(iii) Criteria upon which fieldwork is really assessed

Since in so many cases criteria for assessment are
either unstated or inadequately described, the author has
attempted to piece together from unofficial sources (i.e.
teachers of CSE, O level, A level and retired examiners)
what criteria are used.   These sources indicate that the
following evidence is looked for:

1.   Real experience in the field as opposed to faked
     experience (i.e. classroom dictation, textbook
     diagrams):   a commonsense measure of "Has
     proper geological work been done?"

2.   The work being written-up in the field as
     opposed to being written-up in the classroom.

3.   The content being geological as opposed to
     geographical.

4.   The degree of fullness and completion of the
     work.

5.   The variety of geological experience.

6.   The variety of localities visited in a local
     area.   Some emphasise that a small area should
     be worked on foot rather than scattered
     localities worked by coach.

7.   The variety of rocks studied, i.e. igneous,
     sedimentary, metamorphic;   mineralised and
     fossiliferous.

8.   A variety of rocks of different ages.

9.   The quality of expression in the field report.

10. Neatness.

11. The presence of many diagrams of seeming
     accuracy and quality.

12. The individuality and originality of writing-up.

TABLE 1 FIELDWORK REQUIREMENTS:			
Board Syllabus Date	Number of days in field	Fieldwork content	Skills to be developed
AEB 1973	not stated	Notes. A pamphlet on fieldwork is produced but unfortunately a copy has not yet come to hand *	Making field sketches *
Cambridge Local 1974	10 minimum	The study of a district and the maps of the District. Practical work to illustrate theoretical topics. Reference to structure and relief, the position of springs, the geological distribution of soils, economic products of economic importance	a. Personal observation b. The examination of rocks, minerals and fossils in the field.
JMB 1974	not stated	Any area. Experience in the field. To study the distribution of rock types, fossils, sedimentary and tectonic structures, geomorphic phenomena	Personal observation Experience in the field

AEB = Associated Examining Board

JMB = Joint Matriculation Board
* But see addendum re booklet "Suggestions on the
                                    organisation of fieldwork"

ADVANCED LEVEL OF GENERAL CERTIFICATE OF EDUCATION			
Presentation	Mode of assessment	Criteria of assessment	Percentage of total exam.
Practical note-books to be submitted: to include original field notebook	Teacher to certify authenticity of the work	None stated	10% for all practical books
Not stated but possibly in answers to theory questions	Not stated but possibly through questions in theory paper which are not compulsory	Not stated	None to a little. Depends on choice of questions
a. By original field note-book (not fair copies), b. By illust-ration of answers in theory paper	a. Inspection of field-notebook b. By questions in theory paper.	Not stated	None, but may be used to upgrade borderline candidates or gain odd marks in theory paper
		TABLE 1 continued overleaf	

TABLE 1 continued

Board Syllabus Date	Number of days in field	Fieldwork content	Skills to be developed
London 1973 and draft of new syllabus	10 minimum	An area of the school's choice	a. To undergo adequate instruction b. To become familiar with the geology of a selected area c. Noting personal observations d. To make personal measurements e. to make personal sketches or photographs and annotate them.
Oxford Local 1975	not stated	Unspecified	Ability to keep a record of fieldwork
Oxford and Cambridge 1974	not stated	Study of a district	a. Field observation b. Deductions from observation
WJEC 1974	not stated	Study of a small area by the candidate in isolation or by the class as a group.	a. Experience of study in the field b. Displaying specimens c. Writing a field report

WJEC = Welsh Joint Education Committee

Presentation	Mode of assessment	Criteria of assessment	Percentage of total exam.
Original field notebooks brought to practical	External marking of field note-books	Criteria used by examiners but cannot be divulged	?
By reference in theory papers where relevant	Via answers in theory papers	Not stated	Odd marks may be gained in theory papers
By reference in theory papers	Via answers in theory papers. Question on field work in theory paper but not compulsory	Not stated	None to a little. Depends on choice of questions
a. Display of specimens b. Field reports of individual or group work	Assessment an integral part of the examination	Not stated	?

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	TABLE 2	FIELDWORK REQUIREMENTS:	
Board Syllabus Date	Number of days in field	Fieldwork content	Skills to be developed
Cambridge Local 1974	Not stated	School area or another selected area. Reference to local geological maps. Collection of specimens.	a. Examination of rock exposures b. Observation of agents of erosion and deposition. c. Simple field-sketching.
AEB 1974	3 half or 3 full days	Any area. Stress to be placed on application of geology to every-day life. *See addendum re booklet "Suggestions on the Organisation of Field Work" (O level and A level) 1974.	Adequate field training a. Note-taking b. Field-sketching * See addendum re booklet.
JMB 1973	Not stated	Study of geologi-cal phenomena and structures.	None stated
London 1975	3 half or 3 full days	Not stated	Not stated
Oxford Local 1975	Not stated	a. Any area. b. Collection of rocks, minerals, fossils c. Reference to geological maps	a. Observation and recording of processes of erosion and deposition. b. Observation and recording of relationship between geology and scenery. c. Simple field-sketching. d. Recording textures and structures of rocks.
AEB = Associated Examining Board JMB = Joint Matriculation Board			

ORDINARY LEVEL OF GENERAL CERTIFICATE OF EDUCATION			
Presentation	Mode of assessment	Criteria of assessment	Percentage of total exam.
None	Via questions on the theory papers	Not stated	Small variable % via answers in theory papers
Practical books to be handed in with lab work and fieldwork (original field notebook)	a. Teacher certi- fication of authenticity. b. Not stated	Not stated	10% for practical books
In answers in the theory papers	Via questions on the theory paper	Not stated	Small variable % via answers in theory papers.
Field notebooks sent to the university	Unspecified in syllabus. "Work will be taken into account".	Not stated. Criteria exist but are privy only to examiners	"Taken into account when assessing marks".
? None	Via questions on the theory paper	Not stated	Small variable % via answers in theory papers.

Board Syllabus Date	Number of days in field	Fieldwork content	Skills to be developed
		TABLE 2 continued	
Southern Universities 1971	Not stated	a. The school district b. The study of simple geological maps	a. Observation under natural conditions of agents of erosion and deposition, b. Practice in collection of specimens. c. Simple field-sketching. d. To cultivate scientific enquiry
WJEC 1974	Not stated	The general geology of an area. The study of geological processes in the field including, a. Simple stratigraphical sequence. b. Major tectonic structures. c. Outcrop maps. d. Collection of specimens. e. Examination of contemporary geological processes. f. The relationship of geology to scenery.	a. The discipline of accurate observation. b. The discipline of accurate recording.
Northern Ireland Schools Exam. Council 1975	Not stated	School or any other area. Collection of rocks, minerals, fossils.	a. Sketching geological phenomena b. Collection of rocks, minerals, fossils.

WJEC = Welsh Joint Education Committee

Presentation	Mode of assessment	Criteria of assessment	Percentage of total exam.
In answers in theory paper	Fieldwork question in theory paper compulsory	Unspecified mark schemes	Fieldwork question will carry equal marks
In answers in theory paper	Via questions in theory paper	Not stated	Small variable % via answers in theory papers
Field note-books are submitted for examination together with ancillary practical work	Not stated	Not stated	Not stated

TABLE 3   FIELDWORK REQUIREMENTS:

Board Syllabus Date	Number of days in field	Fieldwork content	Skills to be developed
EMREB 1974 Mode I	3 minimum	a. Study of local area b. Landforms c. Building stones d. Mineral fossil rock collecting e. Geology of rock exposures	a. Accurate recording of data b. Interpreting evidence in rock exposures.
MXREB Draft Mode I dated 1972	3	Unstated but fieldwork said to be invaluable: a significant part of the work	None stated

EMREB = East Midlands Regional Examining Board

MXREB = Middlesex Regional Examining Board

CERTIFICATE OF SECONDARY EDUCATION			
Presentation	Mode of assessment	Criteria of assessment	Percentage of total exam.
Personal observations in answers to written questions. Fully written up account of field visits (a main effort). Rough and final field notes	Inspection of fieldbooks. Internal assessment by teacher. External moderation (no interview)	Criteria stated for assessment of lab. but not field books. Evidence of collection by pupil other than on class visit	With practical up to 15%
Rough and final field notes	Inspection of fieldbooks. Internal assessment by teacher. External moderation	Not stated	With practical 30%

TABLE 3 continued			
Board Syllabus Date	Number of days in field	Fieldwork content	Skills to be developed
NWSSEB 1973 Mode I	2½ minimum	Field excursion recommended in first few weeks. Importance marked by provision of special pamphlet in which it is suggested that short studies are preferable to study of single area. Examples: a. Demonstration of geology of quarry section: rocks fossils sedimentation simple struc-tures (e.g. bedding): economic uses. To be followed by pupils' own work on another but similar quarry. b. Transect: recording all information on six inch map. To be done in pairs. c. Local geology: to visit exca-vations: geo-logy of school grounds: local building stones. d. Geomorphological exercise: river valley, coastal section, glacial valley.	a. Learning from instructor. b. Practical investi-gation by self and in pairs. c. Disciplined observation. d. Interpretation and formation of reasoned conclusions. e. Sketching. f. Photography?
NWSSEB = North Western Regional Examining Board		Extracurricular work welcomed. Collection of spe-cimens can count but excessive coll-ecting discouraged Country code to be taught and strictly observed.	

Presentation	Mode of assessment	Criteria of assessment	Percentage of total exam.
a. Original notes prefaced by list of dated excursions. b. Written account of field studies not consisting largely of handout material or class notes. c. Extra-curricular work.	Internal assessment by teacher who provides: a. A brief confidential account of the work of each pupil. b. A mark out of 30. Extra curricular work to be marked. External moderation.	a. Presentation. b. Illustration. c. Personal observation. d. Personal collection. e. Completeness. f. Originality. g. Labelling, arrangement, usefullness of rock collection. The teacher is advised <u>not</u> to comment on pupils' rate of progress, perseverence, consistency of efforts, reliability in working unsupervised, or mark highly for number and rarity of specimens.	15% 15%

Board Syllabus Date	Number of days in field	Fieldwork content	Skills to be developed
		TABLE 3 continued	
SREB 1972 draft Mode I	Not stated	a. Collect specimens. b. Geological sections should be used to illustrate changing conditions of deposition.	Passive learning: pupils to be shown rocks in situ and relationships demonstrated.
YREB 1972 draft Mode I	Not stated	Not stated	(Not stated but basic objectives of whole assessment are to:- a. Recall basic facts. b. Observe and record basic information. c. Understand information. d. Apply geological knowledge in order to solve problems. e. Draw upon understanding to produce logical argument concerning the information.
WJEC 1973 Mode I	Not stated	Study the home area defined as the area accessible from school. Collection of rocks, minerals, fossils, photographs, maps.	a. Accurate observation. b. Labelling specimens? c. Photography?

SREB = Southern Regional Examining Board

YREB = Yorkshire Regional Examining Board

WJEC = Welsh Joint Education Committee

Presentation	Mode of assessment	Criteria of assessment	Percentage of total exam.
Evidence of fieldwork to be submitted via field note-books.	Not stated	Not stated	20% (but is an optional paper II of practical)
Field note-books.	Internal assess-ment by teacher. External moderation.	Not stated	5%
a. Loose leaf folder or field note-book. b. Personal collection of labelled rocks, minerals, fossils, photos, drawings, maps.	Oral class test. Internal assess-ment by teacher. External modera-tion of sample of pupils.	a. Variety of rocks b. Clear labelling. c. Neat notebook d. Presence of dia-grams, sketches photo-graphs.	With practical 30% (loose leaf folder or notebook 10%)

TABLE 3 continued

Board Syllabus Date	Number of days in field	Fieldwork content	Skills to be developed
WMREB 1972 Mode I	2½ minimum	Study an area. a. Origin and age of rocks and/or minerals in relation to the strati-graphic column. b. The structure and texture of the rocks. c. The fossil content of rocks. d. The effect of geology on economic development.	None stated.
Perkins Mode III 1969	Not stated	The school area. Pupils need to be referred to actual example as often as possible. An individual project of greater depth than is possible in class. a. Thickness and dip of strata. b. Throw of faults. c. Attitude and type of fossils. d. Sketch plans of quarries and quarry faces. e. Sketch cross section of landscape or railway cuttings. f. Landscape sketches.	a. Seeing. b. Recording accurately. c. Field sketching.

WMREB = West Midlands Regional Examining Board

Presentation	Mode of assessment	Criteria of assessment	Percentage of total exam.
a. By answers to written paper. b. Original field note-book. c. Written up report. d. Drawings of specimens collected.	a. By written questions. b. Internal assessment by teacher. c. Work and marks must be available for external assessment.	Originality in writing up.	10%
a. Field note-books. b. Fieldwork report. c. Project report.	Internal assess-ment by teacher. External moderation.	Not stated	Notebook 6.7% Report 3.3% Project 6.7%

4.   <u>Fieldwork arrangements in relation to the</u>
      <u>objectives of science teaching</u>

(i)   Introduction. It is now worthwhile to examine:

      a.   the nature of the fieldwork encouraged by present
           syllabuses in relation to the experience of
           developing other science courses in the 1960's.

      b.   the modes of assessment of fieldwork in relation
           to modern techniques of assessment in science.

      c.   the criteria of assessment for fieldwork in
           relation to modern assessment in science.

      The comments and analyses which follow must rest upon

these assumptions:

      a.   that geology is a science

      b.   that the aim is to educate pupils <u>through</u> not
           <u>in</u> geological science

      c.   that the attempt is therefore to develop
           acceptable methods of teaching science through
           geology

      d.   that fieldwork, and methods of teaching fieldwork,
           as a form of practical work, can and should be
           compared with the best practical work and teaching
           of practical work offered in science in general.

      e.   that in any curriculum we should attempt to state
           what we mean as carefully as possible in order
           that as little confusion as possible should accrue
           from merely linguistic difficulties. All
           syllabuses are intended, within limits, to allow
           teachers freedom to teach as they wish, but it is
           sensible to state as clearly as possible what the
           examination will test, and hence allow judgement
           to be made about where it is possible to leave a
           prescribed route without harming the examination
           prospects of pupils.

      f.   that it is just simply inappropriate, even
           irrelevant, to examine practical work by a theory
           paper alone.

(ii) The development of new curricula, assessment procedures
      and attitudes in science education

      A great deal has happened concerning the development

of methods of teaching and assessing science since the

1960's. Scarcely any effect has been noticeable in
geology teaching and examining so far, though a President
of the Association of Teachers of Geology has pointed the
way. Bassett (1971, p.72) wrote

"It is not an exaggeration to claim that the
teaching in science in general is at the threshold of a
new and dramatic era. ... For the first time a massive
effort is being made by scientists and educationalists
to design entirely new curricula in almost every field
of science."

Early in the decade, Kerr et al. (1963) and Eggleston
(1966) questioned practising CSE and O level physics,
chemistry, biology teachers as to the nature of both the
practical work which they provided for their pupils and
the work they would like to provide. These studies have
been reviewed and added to (e.g. Eggleston and Kerr 1969;
West 1972). At the same time work has proceeded on the
way to go about stating and presenting any syllabus state-
ments with respect to viable practical work. Basic rules
for the identification of precise objectives of science
teaching are now known. Tyler (1933) defined objectives
as "changes in pupil behaviour which it is intended to
bring about by learning." Adams and Torgerson (1964)
stated that objectives should be defined in behavioural
terms. They should be unambiguous precise statements
allowing accurate communication, constitute non-overlapping
categories, be discernible as the product of particular
learning experiences, and each be assessable. Most agree
that when syllabuses are constructed, strategic aims
should be stated, and that definite objectives (i.e.
attainable goals) should be set down in particular parts
of a syllabus (see Table 6).

Objectives are often set down in terms of the
classifications of Bloom et al. (1956), Bradfield and
Moredock (1957), or Gronlund (1970). It is normal to
concentrate on the measuring of both the hierarchically
ranked intellectual (cognitive) skills (knowledge,
comprehension, application, analysis, synthesis, evaluation)

TABLE 4   ABILITIES TO BE EXERCISED IN A GOOD PRACTICAL
          LESSON IN RANK ORDER ACCORDING TO PRACTISING
          TEACHERS AT C.S.E. AND O LEVEL

          (Eggleston and Newbould, in Eggleston and
          Kerr 1969)

4.1.	To think inductively and deductively: to draw conclusions
4.2.	To observe and measure
4.3.	To manipulate
4.4.	To record accurately
4.5.	To understand and follow instructions
(4.6.	- 4.11. unranked)
4.6.	To solve problems
4.7.	To think out experiments
4.8.	To be ingenious
4.9.	To analyse data
4.10.	To work methodically
4.11.	To organise experiments

TABLE 5   THE PURPOSES OF PRACTICAL WORK IN YEARS 3 - 5
OF THE SECONDARY SCHOOL ACCORDING TO GRAMMAR,
COMPREHENSIVE AND SECONDARY MODERN SCHOOL
SCIENCE TEACHERS

(Data combined from surveys of Kerr and West:
West 1972). Kerr's survey concerned 701
science teachers: West's 31 chemistry
teachers.

5.1.   To be an integral part of the process of
finding facts by investigation and
arriving at principles

5.2.   To promote simple common sense scientific
methods of thought

5.3.   To make scientific phenomena more real
through actual experience

5.4.   To arouse and maintain interest in the
subject

5.5.   To encourage accurate observation and
accurate recording

5.6.   To elucidate theoretical work so as to
aid comprehension

5.7.   To give training in problem-solving

5.8.   To develop manipulative skills

5.9.   To fit the requirements of practical
examination regulations

5.10.   To verify facts and principles already
taught

The rank order (most important first) of these purposes was
as follows:

	1	2	3	4	5	6	7	8	9	10
West survey	5.1	5.2	5.3	5.4	5.5	5.6	5.7	5.8	5.9	5.10
Kerr survey	5.5	5.2	5.1	5.6	5.4	5.3	5.9	5.8	5.7	5.10

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TABLE 6   STUDENT ATTRIBUTES SUGGESTED FOR ASSESSMENT IN NUFFIELD ADVANCED CHEMISTRY PRACTICAL WORK

6.1. Skill in observation
6.2. Ability to assess critically and evaluate the outcome of practical investigations
6.3. Ability to plan procedures and techniques for solving practical problems
6.4. Skills in manipulation
6.5. Attitudes towards practical work such as proper use of the laboratory and its facilities: persistence: originality, self-dependence.

TABLE 7   ANALYSIS OF PURPOSES, ABILITIES AND ATTRIBUTES OF TABLES 4, 5 and 6

Intellectual Skills (Cognitive Domain)					
	Level	Category	Abilities and purposes of Tables 4, 5 and 6		
lower order abilities	1 2 3	knowledge comprehension application	4.10 4.1	5.9 5.1 5.6	
higher order abilities	4 5 6	analysis synthesis evaluation	4.1 4.9 4.11 4.6 4.7 4.8 4.1	5.2? 5.7	6.2 6.3 6.2
Practical Skills (Psychomotor Domain)					
			4.2 4.3 4.4 4.10	5.3 5.5 5.8	6.1 6.4
Attitudes (Affective Domain)					
			4.8	5.2? 5.4	6.5

and the manipulative and practical (<u>psychomotor</u>) skills, and to question whether it is possible or desirable to measure personality changes (interests and attitudes - <u>affective matters</u>) with respect to science at all (see NWSSEB Table 3, column 7; but also Bollen 1972 and Duffey 1972). It is considered that any list of objectives for any part of any subject should be carefully specified in terms of the desired balance of low- and high-ranking cognitive objectives. Table 7 presents an analysis of the procedures set down in tables 4, 5 and 6 in terms of Bloom's classification.

Presumably, since there is so much here to choose from and reject, any material is put into a syllabus only because it is important. It is now axiomatic that if the material is important, like fieldwork, it should be assessed. To be assessed it needs to have objectives stated in both behavioural and operationally feasible terms. It is also axiomatic that assessment procedures should not distort acceptable and desired educational processes. The criteria of assessment which are to be used should always relate precisely to the aims and objectives.

In order for all these things to be accomplished, particularly with oral, aural and practical work, it has become accepted that a measure of internal assessment, either continuous (i.e. episodic) or terminal, is necessary. The Schools Council (1973, p. 27-9) lists the strengths and weaknesses of internal assessment procedures succinctly and simply.

All these matters are easy to set down in theory but more difficult to put into practice. As West states (1972, p.148) ...

"learning experiences ... could be regarded as resulting from the interaction between a teacher, his resources and a number of external pressures ... a compromise between what the teacher <u>wants</u> to provide, and what he feels he <u>can</u> provide and what he <u>should</u> provide ... For the

science teacher the nature of the practical work his
classes carry out results from his determined objectives
as modified by resources of time, facilities, equipment,
technicians, and external pressures usually in the form
of exam requirements."

A more fundamental change has involved the educational
system, which has long centred around knowledge and the
teacher. Under the belated influence of Rousseau,
Pestallozzi and Froebel the centre of gravity has shifted
towards the individual learner and his behavioural
characteristics. Harken to Rousseau:

"Teach your scholar to observe the phenomena of nature,
you will soon arouse his curiosity, but if you will have
it grow do not be in too great a hurry to satisfy his
curiosity. Put the problems before him and let him solve
them for himself, let him not be taught science, let him
discover it. If ever you substitute authority for reason
he will cease to reason and become a mere plaything of
other people's thought."

Bassett (1971, p.73) has drawn the geologists'
attention to this view:

"There seems little doubt that, as far as possible, a
method of instruction should have the objective of leading
the child to discover for itself. Telling children and
then testing them on what they have been told inevitably
has the effect of producing bench-bound learners whose
motivation for learning is likely to be extrinsic to the
task - pleasing the teacher, getting into university or
college, or artificially maintaining self-esteem."

The implication is that real fieldwork should occupy
an even higher position in geological education than it
appears to do.

(iii) General comments on fieldwork arrangements in
      GCE and CSE syllabuses

It will be appreciated that the present arrangements
for stating and assessing geological fieldwork as a
practical activity of individual learners of science do
not compare well with the developments outlined in the
previous sub-section. Many statements do not concern
behaviours. Objectives of doing fieldwork are not well
stated. Statements are not clear and unambiguous, so that
communication is difficult. The skills to be developed

are scarcely outlined, and what there are relate badly to
the abilities which are exercised in good science lessons
even when allowance is made for the different nature of
geological science. Some cannot be assessed: many are not.
Most published and unpublished criteria (e.g. p.9; 8-11) of
assessment could relate to any subject, never mind science
or geology. They relate either to the acquiring of
knowledge or low-ranking skills. Criteria (1-7) as set out
on p.9 relate to the professional competence and veracity
of the teacher, who not only enters pupils for this
examination but signifies that they have complied with the
requirements of the syllabus. The examiners are measuring
whether the teachers have complied with the syllabus. The
criteria relate to competence in providing suitable
learning experiences, and are only necessary because, (i)
the syllabus does not state precisely the aims and
objectives of the fieldwork, and (ii) some teachers, many
presumably untrained in science teaching, are not aware
enough to provide suitable experiences off their own bat.
The aim, however, is not to assess the teacher's
competence but the child's. The criteria and the assess-
ment should relate to the degree of approved change in
behaviour (i.e. learning) of the children over a range of
practical skills which relate to real geology.

(iv)   Detailed comments on fieldwork arrangements in
       GCE and CSE syllabuses

       (A) Advanced_and_Ordinary Level of_GCE_

           The number of days recommended for fieldwork is
too often not stated. The ATG A level Survey showed that
some schools interpret the regulations to mean that there
is no need to do fieldwork at all. This proves to be true.
From the statements in the syllabuses, schools could do as
little at O level as they do at A level.

Objectives: (a) The content of fieldwork is imprecisely
stated. There are too few words. These allow too little
emphasis and make for poor communication of ideas. This

may be the cause of so little fieldwork being done by some schools; for it appears to be neglected by the syllabus. The statements compare badly with suggestions and specifications for practical work in most traditional science syllabuses, never mind modern syllabuses e.g. JMB Chemistry A level syllabus B, or the Nuffield schemes. Strangely, the content of O level geology schemes is slightly better specified than A level schemes.

(b) Skills. Imprecise terms; "experience", "keep a record", "adequate instruction", "experience in the field", "become familiar with", lead to poor communication. The learning experiences which are encouraged, if any, are again better stated for O level than A level, where the position is dire. If the only statement in a syllabus concerns passive instruction or demonstration by the teacher, then it appears that that is all that is needed. Who in physics, chemistry, biology would learn techniques and skills by watching? The range of abilities to be developed is too small; smaller for A than O level if words are taken at their face value. Inexperienced teachers receive no help.

Presentation: It is inappropriate to present evidence of practical work and fieldwork by answers to theory questions alone. This is unfortunately the case in many O level science subjects (e.g. physics and chemistry) where logistics are difficult because of numbers. It does not happen in A level sciences. It should not happen in geology if fieldwork is basic and numbers small. Often the field notebook is the only source of data for assessment. Anyone who has seen their variety would doubt their value as a potential measure of the work done. Some guidance could be given as to their arrangement and content. Displays of specimens do not always reflect the owner's diligence and skill: the rocks in the displays are sometimes not his property. It is best to restrict material for displays to specimens worked on and labelled at school.

Mode_of assessment: It is inappropriate to examine
practical work by theory questions alone. In that case
the examination may be reliable overall but it will not be
valid: it will be invalid with respect to statements
about fieldwork, flimsily though the objectives are written.
If the only way to assess fieldwork is by internal assess-
ment then it should be done that way: there have been
precedents within the GCE system (language dictées,
domestic science, dissections in biology, etc.) The size
of the administrative problem is often quoted as a reason
for not having internal assessment. In geology where
entries are less than 2% of the total both at A and O
level, (D.E.S. statistics 1960-73), this cannot be the
cause. Educationally it should not be according to modern
principles. If fieldwork is important, it should be
assessed: if not, it should be dropped.

Criteria_of assessment: These are scarcely stated. Teachers
and pupils deserve to know them. There is no case for
secrecy if criteria are known: it is of course an
embarrassment if they are said to exist and they do not.
The author realises that it is very difficult if not
impossible to mark fieldbooks as they are organised and
presented at the moment, but this is not a good reason for
devaluing the fieldwork which is alluded to in syllabuses.

Percentage_of the examination total score: The marks
given to fieldwork are derisory and emphasise yet again
that the fundamentals are wrong. If something is
educationally important, it should be scored highly. Time
is spent by some teachers on fieldwork. Figures for A
level (see p.7 above   ) refer to a mean of 11.3 days over
two years: indeed the author now knows of a school where
30 days per year are spent in the field. If for argument's
sake we take a mean of 10 days at A level per year, this
(at 6 hours effective work per day) is equivalent to 160
lessons (plus follow-up work) over two years, and compares
with 640 lessons in the whole course (assuming an eight

period week for 40 weeks per year). If some teachers feel
that fieldwork deserves 25% of the time spent on the whole
course, then it is a major activity. It should be scored
at roughly the same proportion in assessment. At O level
(four periods per week for 40 weeks for two years), a three
day field course is equivalent to 24 lessons (plus follow
up work) and is barely 10% of the time.

Backwash: The effect of GCE arrangements on a basic
scientific activity like fieldwork is to allow it to
diminish to nothing in some schools and to pervert its
nature in nearly all. To examine practical work by theory
questions, to allow any kind of book and notes to pass as
a tolerable field notebook tends to encourage teachers to
make fieldwork illustrate theory: fieldwork becomes less
important, and is dealt with by the writing of notes about
an outcrop, or worse, the dictating of notes; not by working
on it. This relates to the curious phenomenon of the
elevation of theory above practice (practical examinations
always count less than theory exams). As Medawar (1967,
p.121-2) puts it "the notion of purity has somehow been
superimposed upon it, and now in a new usage that connotes
a conscious and inexplicably self-righteous disengagement
from the pressures of necessity and use." It relates also
to Anglo-Saxon scientific tradition in schools and
colleges which has been preoccupied with knowledge (and
theoretical knowledge at that) until very recently.

It is to the credit of the few teachers who boost the
mean values of days spent in the field that they refuse to
be diverted. The GCE arrangements are seen to be
professional only in the administrative sense. Boards are
supposed to be the servants of the schools and have
teacher-dominated committees. Is this working in practice?

(B) Certificate of Secondary Education
Number of days: The definition of requirements is a little
better but still patchy. It is still possible to do no
fieldwork and get away with it.

Objectives: (a) Content. This is very well stated in one case (NWSSEB), but absent or imprecise in others. Emphasis and communication in words are still poorly developed.

(b) Skills are reasonably varied and well stated in a few cases but not always very fully. There is a long way to go before a simple statement of the whole range of abilities to be developed is recognisable (see Schools Council 1969).

Presentation: Again there is some variety, but reliance on field notebooks, whose organisation is difficult to control, is weak.

Modes of assessment: are clearly stated. In the best case there is a considerable range of assessment procedures, which enable a wide range of abilities to be assessed quite effectively.

Criteria: are as badly stated as in GCE except in the case of one board (NWSSEB). The criteria, unfortunately, often have little or nothing to do with the scientific behaviours which are being learned and are criticised elsewhere in this article.

Percentage of the total score of the examination: The percentages are very varied. They are comparable to and justifiable in relation to the amount of time spent on the course (10%: calculated for a course of the same length as GCE O level). This means that the examination is valid in relation to the syllabus; the construction of the examination is technically sound. The author and many teachers believe that three days fieldwork per year is more realistic in relation to the development of adequate skills, and this would require an assessment nearer 20%.

Backwash: is generally good. Since they perform the internal assessment, teachers are forced to think hard of the learning experiences which they develop and the criteria of assessment. They can petition their

colleagues on preparatory committees much more easily.
Internal assessment using sound criteria is the only way
of assessing behaviours which have to be performed in the
field, i.e. observing, recording, making hypotheses,
predicting, testing hypotheses by going to another part of
the outcrop. There is, however, a real difficulty of
assessing large numbers. Some, cynics apart, will doubt
the value of internal assessment and external moderation,
and regard it as a glorious charade which leads to a
certification of doubtful value. The author merely points
out the complete absence of unarguable criteria for
comparing grades in different subjects between different
boards in external examinations despite the studies made
by JMB (1966, 1970, 1971) NFER and Schools Council (1970).
No system of moderation is easy to operate, and the author
regards comparability over an area, region or country, as
completely unproven as in GCE. The material, however,
which has to be moderated is taught and the backwash is
very healthy, for teachers are, for the first time really
involved en masse in examining; they are asked to think
about criteria for teaching and assessing; they go out of
their classroom to see other schools' work. The
inexperienced debate, discuss and probe as never before.
This is not to say that difficulties do not arise with
internal assessment: from changes of staff and students,
the strain on relationships between them, and the extra
workload placed on staff. Administrative matters apart,
the examination is on its way to becoming professionally
competent. It is much more so in some areas (NWSSEB) than
others. There is still a long way to go.

5.   Recommendations
(i)   The aim of geological fieldwork is to have pupils
      geologise by themselves.

    Science is a living activity. Primary knowledge is
gained by individual learners doing science practically.
This may require prior instruction and demonstration

(mostly in school), but pupils must do as much geology as

possible by themselves. The former President of the

Association of Teachers of Geology gives the lead,

(Bassett, 1971, p.73):

"If, therefore, we accept the contention that intellectual
activity is the same, whether we are considering the mental
processes of a scientist at the frontiers of science or of
a child in the lower levels of our secondary schools, then
we should consider the child who is learning geology as a
"geologist". ... it is much easier for a child to learn
geology by behaving like a geologist than by doing something
else. That "something else" usually involves what Jerome
Bruner (1965) describes as a "middle language" - class room
discussions and textbooks that talk about the conclusions
in a field of inquiry rather than centering upon the
inquiry itself."

Syllabuses should state clearly, preferably in the first

paragraphs, that learning geology starts in the field, and

that although time will restrict opportunities, pupils

should each and individually have the opportunity to develop

the skills cited below as soon as possible in their course,

preferably in the first lession, and thereafter as

frequently as possible.

(ii) Preferred organisation of fieldwork

    At least two periods of personal investigation are

suggested per field day at CSE and O level, but longer

periods are obviously feasible at A level. The earliest

excursions should use carefully structured exercises whose

instructions are personalised via worksheets.

(iii) The objectives of fieldwork can be stated thus:

a.   To understand and follow instructions.
b.   To work methodically and individually except on
      rare occasions.
c.   To observe as accurately as possible in a disciplined
      way.
d.   To manipulate and use relevant simple tools (a list
      of appropriate tools could be stated: clinometer,
      orienteering compass, tape measure or rule, pencil,
      paper, on occasions a hammer, a weak acid bottle,
      a penknife).
e.   To develop the habit of measuring quantitatively
      using SI units: to measure dips, azimuths, bed
      thicknesses, sizes of grains, number of fossils etc.

f.   To record as accurately and methodically as possible
       at the outcrop. This can be done on loose paper
       (later to be put in a file) or in a field notebook
       (more long living but more likely to be lost) or by
       a camera. A list of suitable ways of recording data
       could be inserted, e.g. making a map of a small area,
       perhaps a quarry floor or an intertidal area, or
       making a scaled diagram (the author never used the
       word sketch).
g.   To locate and reference any records; the test and the
       criterion for assessment being that an observer could
       go to and locate the exact spot many years later.
h.   To locate, recognise and solve problems.
i.   To think inductively and deductively: to draw
       conclusions and make hypotheses.
j.   To think of ways of testing hypotheses. A list of
       suitable activities could be given, e.g. going to other
       parts of a quarry, stream or cliff and making new
       observations.
k.   To follow up fieldwork and field identifications by
       making laboratory tests and identifications, and
       processing samples brought in from the field.
l.   To analyse data and to write a report wherein the data
       are synthesised and evaluated.
m.   To conserve geological data and countryside in general
       by reducing hammering and following country codes.

    The variety of these objectives is such that some may
be omitted for younger or less able pupils. Other objectives
could be added, but they ought to be constructed according to.
Adam's guidelines (Adams and Torgerson 1964). These
objectives all concern behaviours which are learning
experiences.

(iv) Activities suitable for school fieldwork

    Lists of activities which could be carried out by school-
based parties are rarely published. Most activities need
the careful preparation of individual worksheets before they
are structured satisfactorily in relation to the objectives
of the previous section. It is a great challenge to the
teacher to produce two exercises per field day and it
requires a great deal of preparation time. Once prepared
and perfected, however, in terms of range of content and
balance of skills, the exercises can be repeated from year
to year, being only modified for the better. Exercises
could be exchanged between schools. Some of the best

ought to be published. They need to be in much greater detail than those of <u>Nuffield Secondary Science, Section 8.4: The Earth</u>; (Leigh 1970).

(v) Objectives should be assessed both in the field and back at school

Each objective of section (iii) is operationally assessable or they would not be properly constructed objectives. Each agreed objective is a criterion for assessment whatever the content of the fieldwork exercise. Since each of the first ten objectives relate only to the field, assessment must therefore take place in the field. Failing the presence of an external examiner for each school, and the possibility of setting up a special test, such as developed at the University of Oxford, the only person able to do the assessing is the teacher: the CSE boards and teacher committees are quite right in having a component of internal assessment and requiring it to be externally moderated. Objectives k, l and m can be accomplished both in the field and in the study or class-room, and additional criteria will be needed to assess the quality of these behaviours. For the purposes of reporting internal assessment, it is necessary to reduce the number of categories of assessment to say, five. The following are suggested for CSE and O level, the last of which would be scored at twice the value of any other single category.

1.   Ability to observe
2.   Ability to record
3.   Ability to manipulate
4.   Ability to make hypotheses, predict, test hypotheses in the field
5.   Ability to state a problem; analyse, synthesise and evaluate data relating to the problem and write a report explaining the solution of the problem in a simple way.

For A level the five categories might be different and include some of those of Nuffield 'A' level chemistry (Table 6).

We should <u>not</u> assess how pupils take instruction

or learn from demonstrations, or copy notes dictated at
outcrop, or copy maps and diagrams from guides. Most of
the criteria of assessment for A, O and CSE syllabuses
at the present are inappropriate.

(vi) Feasibility and tactics in organising fieldwork

        Some may say that headmasters and colleagues will not
wear. this "fieldwork lark". But at some time the head-
master allowed geology into the curriculum of the school
and it was surely pointed out to him what was required to
do the job properly. Once that decision was made then
all efforts should be made to accomplish the task
professionally. The author has yet to meet a headmaster
who does not respond positively and sympathetically to a
member of staff who goes to him with a well-prepared
argument regarding what is desirable for the proper
teaching of his subject. The argument should be backed by
a pre-prepared series of worksheets which have been
submitted to the headmaster beforehand. These will
detail the fieldwork learning experience through which
he intends his pupils to pass both on a coach and
during two periods of personal investigation (each of
two hours) during the course of a field day. With such
approaches the teacher is likely to get his way before
long. If when a subject has been accepted as part of
the curriculum a headmaster stops a teacher doing what
he considers essential for his teaching then he is
close to obstructing the course of education. The
same arguments go some way to mollifying obdurate
colleagues. Regular afternoons set aside for geology
or a double period at the end of the day which can
stretch to teatime are not impossible to organise.
Some teachers prefer these short opportunities to those
presented by field days. The day before halfterm or full
term are the most obvious times which are most readily
agreeable for field trips, but it is essential to plan

some short fieldwork, if not a full-day excursion, in the first week. Lucky is the school with rocks in the grounds or the road outside, or with a stream in a local park, so that the afternoon or double period can be used.

At the university level, the Oxford University finals examination in geology compares very favourably in intent, organisation and assessment procedures, with the principles of teaching and assessing science which have been outlined in this article. The normal university practice of marking fieldwork by assessing the quality of a student's map (at a distance) and reading his thesis (often without specifying criteria of assessment) is less commendable, and has all the difficulties associated with the marking of a CSE project, or indeed a project at any level.

Addendum

Since this paper was written, copies of the AEB syllabuses for 1974 and 1975 have come to hand. In both reference is made to the new (1974) version of a pamphlet entitled "Suggestions on the organisation of fieldwork". This booklet is, in the author's opinion, quite excellent in the way it sets out the content and skills to be developed by O and A level pupils. The suggestions are detailed, practical and organisationally possible. They correspond closely with those advocated in this paper. Laboratory work directly relevant to field excursions is included in the assessment of O level. The method of assessment, by marking field notebooks by undisclosed criteria, remains the same, and is open to the same criticisms made in this paper of earlier and similar syllabuses. In the preface to the O level syllabus greater stress is laid upon fieldwork than hitherto.

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NOTES ON HUNSTANTON RED ROCK FOSSILS

H. Le Strange*

Marine Reptiles: a few odd bones of these are seen in The
Sedgwick Museum of Geology in the University of Cambridge,
and are in the special show case containing a fine collect-
ion of Red Chalk Fossils, all from Hunstanton. However it
is very, very rare that any worthwhile reptile remains are
to be seen, though indeterminate fragments are more common.
Fish (teeth and bones): are scarce compared to those in
the White Chalk of Hunstanton cliffs.
Mollusca: I refer you to "The Geology of Norfolk" (1970),
where on page 290 Dr. R. Casey has provided a revised list
of fossil Mollusca from the Hunstanton Red Rock.

     Lamellibranchia (= Bivalves). Splinters of Inoceramus
occur by the million, and more or less perfect specimens are
also quote common.

     Gastropoda. I have seldom found these.

     Belemnites. The Red Rock is absolutely riddled with
specimens of small species of these, some over 5 cm long.
There are no large species, as occur in some formations.

     Ammonites. Well preserved specimens are on the rare
side, though of course there are many poorer specimens.

     This is also true of the Nautiloids, and it applies to
Cymatoceras hunstantonesis (Foord and Crick).

Brachiopods. After belemnites the next commonest fossils
are the brachiopods, known as Terebratula dutempleana
(d'Orbigny). Specimens as large as the one shown in
"British Mesozoic Fossils" are not too common. They vary
greatly in size, and even shape, and may in due course get
divided into several varieties.

Echinoderms. Do not forget to look out for the Crinoid

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Torynocrinus with stem segments fused into a continuous circular column. This is fairly common, though a perfect specimen is not so often found. They are very fragile and difficult to extract. There is also the heart urchin _Cardiaster_. It is fairly common, and there are some of a "_Cidaris_" type.

Corals. The one and only species I so far know of in the Red Rock is of the solitary type, only $1\frac{1}{2}$ cm in diameter and known as "_Podoseris mammiliformis_" (Duncan). Only once have I found a specimen with two or more buds, though it is a common fossil at Hunstanton.
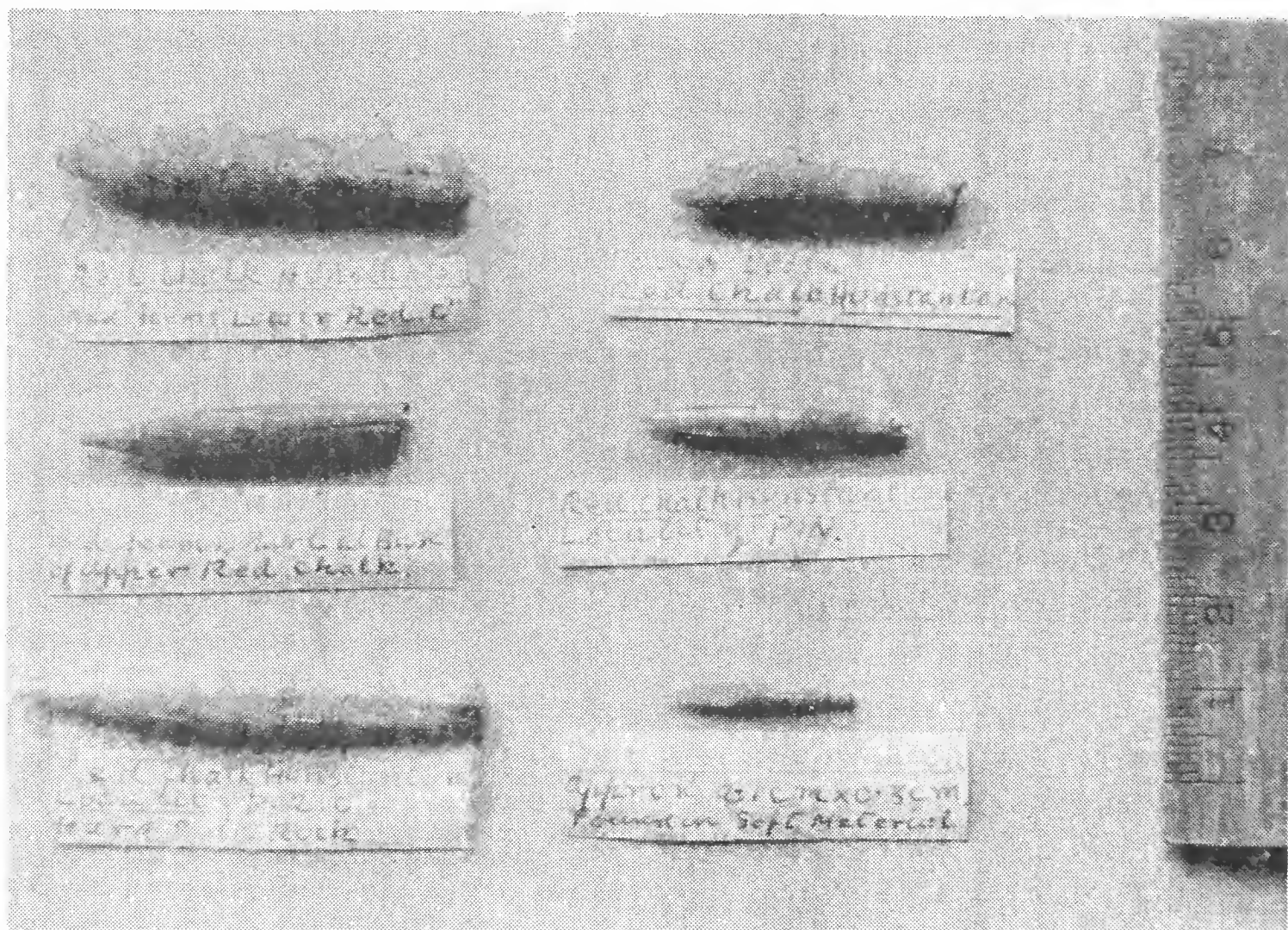
Neohibolites specimens from the H. Le Strange collection - Hunstanton Red Rock

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The Geological Society of Norfolk exists to promote the study and knowledge of geology, particularly in East Anglia, and holds monthly meetings throughout the year.

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